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OTTO KERNER, *Governor*

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PRESIDENTIAL ADDRESS

PROBLEMS OF INTERPRETING THE BEDROCK SURFACE OF ILLINOIS

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One of the traditions of the Illinois State Academy of Science is that the retiring president discuss some topic of scientific research, or education, in which he has a personal interest. This tradition seems worthy of perpetuation, at least as a means of emphasizing the objectives of the Academy, and it is my sincere hope that those of you who are outside of my own area of research will find something of interest in these comments.

As my contribution to this succession of discussions, I wish to consider briefly some of the problems that one encounters in any attempt to interpret historically the development of the topography on the bedrock of Illinois. Over much of Illinois, the bedrock surface is obscured by glacial, alluvial, and eolian deposits that range up to several hundred feet in thickness, and for the most part, therefore, it is a buried topography with which we are concerned. As a somewhat naive graduate student, I first became involved in the interpretation of this bedrock surface in 1937 when, with the aid of the Illinois State Geological Survey, I undertook a study of the history of the abandoned valley of the Ancient Mississippi River (Frye, 1938). Since that time, I have had only intermittent opportunities to continue work on this problem, but others have contributed significant data and interpretations and I have continued to be interested in considering the regional implications of these data in the solution of the problem of reconstructing the history of this bedrock surface.

Illinois occupies a unique position in the drainage history of the vast interior of the North American continent. The southern tip of the state includes the northern limit of the Mississippi Embayment along which the Tertiary marine invasion penetrated most deeply into the continental interior. Forming the boundaries of our state are the Mississippi, Ohio, and Wabash Rivers — and the mouth of the Missouri River is at our western border. The gulfward outlet for part of the evolving glacial Great Lakes was by way of the Illinois River valley, which extends diagonally across the state. In other words, Illinois has been a focal point for the streams that sculptured the bedrock topography of the continental interior and, thus, our area may be critical to the interpretation of the regional erosional history of much of the Mississippi River basin.

The shape of the bedrock surface

over most of Illinois, masked by its mantle of glacial deposits, has been described by Horberg (1946, 1950), and the erosional history of the unglaciated "driftless area," which includes the northwestern corner of Illinois, has been analyzed by Trowbridge (1921). In many parts of Illinois, the relief on the eroded bedrock surface is greater than that of the present topographic surface because the deep valleys that were cut into the bedrock are invariably filled, at least partly, with Pleistocene deposits, whereas bedrock extends, in general, to the highest points of the present topography. Nevertheless, the shape of the bedrock surface is generally similar to that of the present surface in that it is characterized by relatively broad and flat tabular uplands that are notched by sharply incised valleys.

These tabular uplands are not all at an accordant or consistent level, but within the uplands there are several "preferred" elevations that have been considered to be the product of the partial destruction of former, relatively flat surfaces that had been developed by several distinct cycles of erosion (Trowbridge, 1921, 1959; Horberg, 1946, 1950; Leighton, Ekblaw, and Horberg, 1948). It is generally agreed that the erosional incision that produced the deep bedrock valleys took place after the last cycle of planation, or "peneplanation," that developed these extensive upland plains. There is marked disagreement, however, concerning the age and the sequence of events that produced the erosional trenching below these upland surfaces and thus gave rise to the systems of major valleys — both past and present. At one extreme in the range of historical interpretations is the conclusion that the topography of the bedrock surface, including the excavation of the deepest bedrock valleys, had developed to essentially its present form during the Tertiary Period (that is, prior to the first episode of continental glaciation), and that during the Pleistocene (or glacial) Period the erosional history of Illinois consisted of little more than the burial of a former landscape. At the other extreme of interpretation is the view (Frye, 1938) that the deepest erosion of the bedrock valleys did not take place until after the advance of the Kansan glaciers, which concludes, therefore, that this event took place at a point in time nearly halfway through the glacial age.

It is true that we are dealing with differences of interpretation based on inadequate and incomplete data, many of which are themselves subject to differences in interpretation. When we consider the means that may be used to resolve such a marked difference of opinion, it appears that there are three general approaches that may be helpful. These are, first, the comparison, or analogy, of the relationships as we see them in Illinois with other parts of the Mississippi drainage system where the physical events, including the erosional history, have been independently dated. We may use a second approach to the problem by determination of the ages of the deposits that rest upon the various elements of the bedrock surface in Illinois and then use these dates as limiting points in the development of the surfaces on which the deposits rest.

And third, we may use the genetic implications of the shape and character of the surface itself as a guide to the erosional history. Let us briefly examine these several lines of evidence.

In using the first approach to our problem, when we search for regions within the present Mississippi River drainage basin with which to establish analogies with dated sequences of events, we are confronted with the fact that a well established late Tertiary and early Pleistocene chronology does not exist in the eastern or northern parts of the basin. When we look southward toward the Gulf, we find that the Tertiary chronology is based on the marine sequence and that the nonmarine Pleistocene deposits are largely correlated with events in our own region. It appears that the most profitable direction to look for a meaningful analogy is toward the west and southwest, because in that part of the basin we find a nonmarine stratigraphic sequence extending throughout the late Tertiary and Pleistocene that has been correlated by vertebrate and invertebrate fossils, as well as by physical stratigraphy. The type areas of the two earliest episodes of Pleistocene continental glaciation occur in the Missouri basin (Frye and Leonard, 1952) and these early glacial stages have been integrated with the stratigraphic sequence in the Great Plains, which serves to place them with relation to a well dated sequence of late Miocene and Pliocene strata (Frye, Leonard, and Swineford, 1956; Frye and Leonard, 1959). Toward the southwest, beyond the direct influence of continental glaciers, the deposits and terraces in the Red River basin (Frye and Leonard, 1963) have also been integrated with the Great Plains' chronology. As the Red River and the Missouri-Kansas River system are major tributaries to the Mississippi, their erosional histories should be pertinent to our problems in Illinois. These two basins present distinctly different bases of comparison as the Missouri-Kansas Valley was directly invaded by continental glaciers, whereas the Red River basin was beyond the reach of continental glaciation and its history therefore reflects only the regional climatic changes and structural events. The evidence from these western tributary basins (Frye and Leonard, 1952, 1963) strongly indicates (1) that the late Tertiary drainage lines were at relatively high levels and were associated with surfaces comparable to our tabular uplands; (2) that marked valley incision took place during the Nebraskan; and (3) that the Kansan glacial stage witnessed the final establishment and much of the deep trenching of major valleys in the positions they now occupy. It is true, particularly in the southwest, that valley dissection during the Illinoian and Wisconsinan generally exceeded the depth of the Kansan valley floors and locally produced drainage changes, but otherwise did not profoundly modify the bedrock topography. It appears that our first approach supports the interpretation of a young age for the deep bedrock valleys, but this cannot be considered conclusive evidence until the terraces have been traced from these areas into the Illinois region.

When we consider our second ap-

proach to the problem by the dating of deposits that lie upon and above the bedrock surface in Illinois, we discover that this method becomes progressively more precise as we approach the Recent in age (Leverett, 1899; Frye and Willman, 1960; Willman, Glass and Frye, 1963). Some unconsolidated deposits on bedrock (e.g., in Adams and Pike Counties) may be as old as Cretaceous and thus define in a present upland the position of a surface that developed prior to the Tertiary. Many deposits of chert gravels in upland situations in southern and western Illinois have been called "Lafayette type" and have been assigned a Tertiary age by many workers. On the basis of these age assignments it generally has been held that the bedrock upland surfaces were all developed prior to the end of Tertiary time, and further, that the supposed absence of Pleistocene water-laid deposits on these uplands implies that the trenching of the deep valleys also took place before the end of Tertiary time. Although it is probable that ages from Cretaceous through Tertiary are represented by some of the upland gravels in Illinois, many, if not most of these deposits have not as yet been dated with certainty. Some of the upland gravel deposits, as exemplified by exposures in southern Calhoun County, contain pink quartzite boulders more than two feet in diameter, and exceedingly sparse cobbles of igneous rock; such deposits are most reasonably explained as the product of glacial transport — probably by the Nebraskan. As these deposits of probable Nebraskan age occur on tabular divides above deep bedrock valleys their presence casts doubt on the existence of the deep valleys at the time of their deposition.

In Illinois we find that confirmed localities of Nebraskan glacial till are so rare as to have minor value to the solution of this problem. However, there are a few water-laid gravel deposits for which a Nebraskan age is fairly well established, for example north of Banner in Peoria County. The position of these deposits suggests that by Nebraskan time the major valleys were incised below the bedrock tabular uplands, but probably were well above the position of the present flood plains of the major valleys.

Since neither Tertiary deposits nor Nebraskan glacial till serve to define with certainty the age of the deep bedrock valleys in Illinois it appears that the relation of Kansan till (that is, the second major glacial episode) to the bedrock surface may be critical to our problem. As the position of the Ancient Mississippi Valley has been described (Horberg, 1950; Frye, Glass and Willman, 1962) as leaving the present Mississippi above Moline and trending east south-east to the bend of the Illinois River in Bureau County, and approximately along the Illinois Valley to the Mississippi near Alton, it would appear that there should be ample opportunity to relate Kansan till to this major valley trench. Unfortunately, however, the Kansan glaciers from the west fell just short of reaching this valley and it is not known whether or not the Kansan glaciers that invaded Illinois from the northeast reached this far to the west (Willman, Glass and Frye, 1963). Such

a geographic pattern deprives us of the possibility of relating the stratigraphy of tills of Kansan age to the trench of the Ancient Mississippi Valley. Also, this same geographic pattern causes one to speculate as to the possibility that these glacial fronts may have been the barriers that served to establish the course of this major stream. Definitive use of this approach must await refined subsurface studies in east-central Illinois of correlations of the several till sheets and the relation of these tills to the bedrock valleys of eastern tributaries to the Ancient Mississippi River.

In spite of the uncertainties in the use of this method of establishing Tertiary and early Pleistocene dates for bedrock sculpture, when we reach Illinoian time the stratigraphy of the deposits overlying the bedrock shows us conclusively that the major bedrock valleys had been cut into their deep channels before the advance of the Illinoian glacier. The Ancient Mississippi River, which had temporarily been diverted to a western course by the advancing Illinoian glacier, returned to its former course, reflected in the topography of the till plain surface by sags over the deep erosional valleys, after the withdrawal of the last of these pulsating glaciers. This ancient course, although it was roughly parallel to the position of the present Illinois Valley, was somewhat east of it in Putnam, Marshall, Woodford, and McLean Counties, and it joined the trench of the present Illinois Valley by way of the lower Sangamon Valley in southwestern Mason County. The major stream was not forced into the present position of the Mississippi River until the first advance of the Woodfordian glaciers during the later part of Wisconsinan time. The Mississippi was subsequently prevented from returning to the ancestral course by the presence of prominent end moraines across the position of the buried bedrock valley in Bureau County.

Now let us turn to our third approach to the problem, by consideration of the genetic implications of the shape or form of the bedrock surface itself. Trowbridge (1921) utilized this approach in his detailed analysis of the several accordant levels within the divide areas in the unglaciated region of the upper Mississippi Valley "Driftless Area," and Horberg (1946, 1950), by use of extensive subsurface data, has analyzed the planated surfaces below the drift in Illinois. Studies that have been made of the upland bedrock topography, both where it is buried by glacial deposits and in the unglaciated region, have mostly reached the conclusion that several cycles of regional erosion occurred before the event of major dissection that produced the deep bedrock valley trenches. If several distinct cycles of erosion did in fact occur, each of them must have progressed to an advanced stage to have produced the broad flat areas that are ascribed to them. It is not our purpose here to attempt to determine if these seemingly accordant levels are the result of multiple cycles of peneplanation caused by sudden marked changes in base level, or if they were produced by one continuing episode of erosion and therefore are the reflection of differences in the erosional resistance of various bedrock

units, or, perhaps, if they may even represent successive pediplains. It is sufficient for our purposes to agree with the overwhelming weight of evidence that the upland surfaces had been developed by the end of Tertiary time and that during Pleistocene time they were modified only locally by glacial erosion. Therefore, we are again brought back to the problem of the interpretation of the deep bedrock valleys cut below these upland surfaces. When we consider these bedrock valleys from the viewpoint of their morphology we find that we have both regional data (Horberg, 1950) and local details that are not compatible with an erosional development expectable under conditions of structural stability and uniform base level control over an extended period of time.

The local details of morphology, although suggestive, are far from conclusive in the solution of our problem. The significant features of the local topography include precipitous valley bluffs suggestive of youthful canyon cutting, both at the surface and buried beneath the Pleistocene fill; sharply faceted spurs, particularly along the lower part of Illinois Valley; tributaries whose bedrock floors have oversteepened gradients adjacent to the master valley; and a drainage pattern that certainly is not reminiscent of a long established and well adjusted drainage system.

The outstanding regional morphologic anomaly of the major valleys is the gradient of the bedrock floor of Ancient Mississippi Valley. For a distance of about 350 miles south of the northern border of Illinois the floor of this bedrock valley, as contoured by Horberg (1950), declines less than 50 feet in altitude, which indicates the equivalent of a uniform gradient, if it is in fact uniform, of less than 1/7 of a foot per mile. Such a gradient is clearly inconsistent with the shape and pattern of this erosional valley. Furthermore, we are confronted with the necessity of explaining this anomalous gradient across a region where the structure of the bedrock gives us no helpful clues.

A reasonable explanation of gradients in these bedrock valleys may be furnished by the concept of temporary warping of the crust produced by the loading and unloading of glacial ice during the Pleistocene. Such a concept has been suggested as the explanation of the anomalous gradient of the bedrock valley floor of an abandoned drainage way through which Kansan outwash discharged in central Kansas (Frye and Leonard, 1952, p. 190). Although no direct measure of crustal depression by earlier glaciers is possible, it has been estimated that the last maximum of the Wisconsinan glacier depressed the crust more than 2000 feet in central Canada (Farrand and Gajda, 1962, p. 10). Unless we assume that the rocks of the crust are without strength there must have been a complementary "forebulge" surrounding this depressed area. Such an isostatic "forebulge" might be compared to the low ridge that rises around a pebble dropped on the surface of a pool of partly congealed tar. Furthermore, if we relate the central isostatic depression and peripheral elevation to a simple lever, a positive movement at the crest of

the "forebulge" of more than 200 feet seems reasonable.

In order to gain a better quantitative view of the crustal situation, L. D. McGinnis, geophysicist with our Survey, has calculated volumes of crustal material that would be involved if we assume a symmetrical ice mass comparable in maximum dimensions to the Wisconsinan and with the amount of central depression assigned to this last glaciation. He suggests that the total volume of rock displaced to accommodate such a depression beneath this idealized ice cap amounts to about 2.6 X 10^5 cubic miles. This volume would have to move into the "forebulge" area unless the earth behaved like a liquid, which it doesn't. If this volume were moved into a 400 mile wide ring around the generalized "circle" of the ice cap the peripheral ring would be raised in elevation about 420 feet. If this volume were moved into an 800 mile wide ring, the ring would be raised roughly 160 feet.

If we project these relations backward in time it is apparent that both Illinoian and Kansan glaciers were more extensive, at least in Illinois, than were the Wisconsinan glaciers and therefore it is safe to assume that the isostatic movement of the surface was as great or greater than these approximations during the Kansan and Illinoian glacial episodes, and that they may have equaled this amount during the Nebraskan.

Another factor that is pertinent to our analysis of the effect of isostasy on valley development is the timing of the causes and effects. Rebound after glacial unloading is known to lag by some thousands of years before the crust approaches a return to equilibrium (Farrand and Gajda, 1962) and it is reasonable to assume that the subsidence of the peripheral bulge must also lag behind the removal of its cause. Also, the speed with which glaciers are know to have advanced and retreated (Frye and Willman, 1960) suggests that isostatic crustal movement lagged behind the causative event. These time relations lead to the conclusion that when continental glaciers were advancing rapidly they were riding up onto the back side of their own induced "forebulge", and that when they were retreating rapidly a topographic depression generally occurred between the margin of the glacier and the back-slope of the peripheral swell or forebulge.

When we consider the locations, shapes and gradients of the deep bedrock valleys of the Illinois region in light of the foregoing it appears that many of the apparent anomalies may be explained by valley incision below a temporarily up-warped surface during and immediately following episodes of continental glaciation, and that the present gradients of the bedrock floors of the deep filled valleys are quite different from the stream gradients that existed while these sharply incised valleys were being cut.

If a stream were forced across the position of a forebulge by the physical presence of glacier fronts it seems certain that the large volumes of water known to have been present during episodes of glaciation — and therefore flowing down these abnormally steep gradients — would have produced rapid incision of val-

leys characterized by a youthful morphology. Thus, positions of major drainage lines would have become fixed before the complete dissipation of the glaciers and before isostatic readjustment could have been far advanced. As the interval of rapid and deep valley cutting must have been followed by the subsidence of the forebulge area and the resultant flattening, or even reversal of the gradients in segments of the major valleys, the final result would be overdeepened valleys cut in bedrock and subsequently partly filled by alluvial deposits. Indeed, this is the situation as we find it in Illinois. It is interesting to note that the long segment of essentially no gradient in the bedrock valley of the Ancient Mississippi is within a region that should have been strongly influenced by forebulges of both the Kansan and the Illinoian glaciers, and that might also have been similarly influenced by the Nebraskan glacier. Consideration of this approach to the general problem of genetic interpretation of the bedrock surface of Illinois may prove to be a fruitful field for detailed research in the future.

In this brief review it has not been my intention to attempt definitive answers to the many questions involved in the interpretation of the history of the development of the bedrock surface of Illinois, but rather to point out some of the problems as they appear to me and to suggest some of the possible lines of attack on these problems. If by so doing I have helped to stimulate new thought and activity, I will have been successful.

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ALKYLAMINOMETHYL HYDROQUINONES AND RELATED COMPOUNDS

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GAROLD GOKEN, and GEORGE VAN LEAR
Millikin University, Decatur

Introduction

Von Braun and Rover (1903: 1196) reported the condensation of dibenzylamine and formaldehyde resulted in the formation of tetrabenzyldiaminomethane.

Clarke, Gillespie, and Weishauss (1933:4571) found that tetrabenzyldiaminomethane was reduced to some tertiary amines with formic acid. They also indicated that methylenedipiperdine was reduced under similar conditions to give 45.3% methylpiperdine and 52.7% piperdine isolated as the benzenesulfonyl piperdine. They reported that secondary amines, excepting dimethylamine, were converted to the N-methyl derivatives in the presence of formaldehyde and formic acid.

Burke (1949:609), Burke and Weatherbee (1950:4691), Burke, Hammer, and Weatherbee (1961: 4403), reported on reactions of phenols with N-methylol derivatives obtained by condensing primary amines and formaldehyde. Bruson and MacMullen (1941:270), and Caldwell and Thompson (1939:765), reported similar condensations involving phenolic compounds with secondary amines.

Discussion

In view of the work of Clarke and his co-workers, in this investigation experiments were undertaken to determine if dibenzylamine and formaldehyde react to form N-methyloldibenzylamine which would further condense with dibenzylamine to form the tetrabenzyldiaminomethane. In view of the reduction of the latter compound with formic acid, investigations were carried out to determine if it would dissociate in solution to dibenzyl amine and its N-methylol derivative.

Condensations under a variety of experimental conditions of dibenzyl amine, formaldehyde, and parabenzyloxphenol resulted in the good recovery of the phenol and in the isolation of over 96% yield of tetrabenzyldiaminomethane. Refluxing of the latter compound with formaldehyde and parabenzyloxyphenol gave similar results. This indicated that the postulated N-methyloldibenzylamine reacted with dibenzylamine easier than with the phenol.

Condensations of benzyl amine, formaldehyde, and para-benzyloxyphenol in a 1:2:1 mole ratio under a variety of experimental conditions gave good yields of 3,4-dihydro-3-benzyl-6-benzyloxy-1,3,2H-benzoxazine. Similar results were obtained at room temperature, refluxing in methanol solution, or refluxing in dioxane solution. However, similar condensations of benzylamine, formaldehyde, and para-benzyloxy-

phenol in a 1:1:1 mole ratio respectively, failed to undergo a condensation; the para-benzyloxyphenol and the benzyl amine as its hydrochloride salt were recovered nearly quantitatively.

Previous investigations by Burke, Hammer, and Weatherbee (1961: 4403), indicated that benzylamine readily condensed with hydroquinone and formaldehyde. The benzylamine and formaldehyde were interacted in the mole ratio of 1:2 respectively and N,N-dimethylolbenzylamine was postulated as the intermediate. The N,N-dimethylolbenzylamine then reacted with hydroquinone in a 2:1 mole ratio respectively to give two isomeric benzoxazines, 3,8-dibenzyl-2, 3,4,7,8,9-hexahydrobenzo 1,2-e,4,5-e′ bis-m-oxazine (compound No.1) and 2,9-dibenzyl1,2,3,8,9,10-hexahydrobenzo 2,1-e,3,4-e′ bis-m-oxazine (compound No. 2).

In this investigation condensation of benzylamine, formaldehyde, and hydroquinone in a 1:1:1 mole ratio failed to give 2-benzylaminomethylhydroquinone, the expected product if N-methylolbenzylamine were postulated as an intermediate. Similar condensations involving benzylamine, formaldehyde, and hydroquinone in a 2:2:1 mole ratio likewise failed to give the expected 2,5-bis(benzylaminomethyl)hydroquinone. Condensations of benzylamine, formaldehyde, and hydroquinone in a 1:2:1 mole ratio with view of securing the monobenzoxazine 3,4-dihydro-3benzyl-6-hydroxy-1,3,2H-benzoxazine resulted in the isolation of the two isomeric bis-benzoxazines (Compounds No. 1 and No. 2) previously mentioned above.

An indirect approach to the preparation of 3,4-dihydro-3-benzyl-6-hydroxy-1,3,2H-benzoxazine was investigated. It was found convenient to prepare 2-benzylaminomethyl-6-benzyloxyphenol hydrochloride by warming 3,4-dihydro-3-benzyl-6-benzyloxy-1,3,2H-benzoxazine with alcoholic hydrochloric acid. The resulting hydrochloride salt was neutralized with sodium bicarbonate, or an aqueous solution was treated with monoethanolamine, to give the free Mannich base. Treatment of the free base with formaldehyde readily converted it in high yield to the starting oxazine indicating that the benzoloxy group was not cleaved by the alcoholic hydrochloric acid.

Warming of the 2-benzylaminomethyl-6-benzyloxyphenol with 37% aqueous hydrochloric acid for ½ hour readily cleaved the ether and 2-benzylaminomethyl hydroquinone hydrochloride was isolated in good yield. The corresponding free base was secured by neutralization with potassium bicarbonate. Upon warming the 2-benzylaminomethyl hydroquinone with a methanol solution of formaldehyde in a 1:1 mole ratio gave good yields of 3,4-dihydro-3-benzyl-6-hydroxy-1,3,2H-benzoxazine. Upon reaction of the latter compound with a dioxane solution of formaldehyde and benzyl amine in a 1:2:1 mole ratio resulted in the isolation of the two isomeric bis benzoxazines (compounds No. 1 and No. 2).

Considerable time was spent investigating methods of converting 2-benzylaminomethyl-6-benzyloxyphenol to 2-benzylaminomethylhydroquinone. The conventional use of hydroiodic acid, and other methods of splitting ethers failed to give good

results. The use of 37% hydrochloric acid under relatively mild conditions was found to be a convenient method. Splitting of other benzyl ethers was studied. Para-benzyloxyphenol was readily converted in high yields to hydroquinone.

Condensations of other primary amines or secondary amines, formaldehyde, and para-benzyloxyphenol, hydroquinone, or other phenolic compounds were investigated. Although dibenzylamine, formaldehyde, and hydroquinone in a 2:2:1 mole ratio respectively failed to yield the expected 2,5-bis(dibenzylaminomethyl)-hydroquinone, yields in excess of 75% of 2,5-bis(dimethylaminomethyl)-hydroquinone were readily secured. Reactions of dimethylamine, formaldehyde, and hydroquinone in a 1:1:1 mole ratio respectively resulted in the isolation of 2,5-bis(dimethylaminomethyl)-hydroquinone and not the expected mono derivative, 2-demethylaminomethylhydroquinone.

Experimental

3,4-dihydro-3-benzyl-6-benzyloxy-1,3,2H-benzoxazine. To 30.6 ml. of 40% formaldehyde (0.4 mole) in 1-propanol dissolved in 50 ml. of dioxane at 10 to 15°C. was added 22 ml. (0.2 mole) of benzyl amine with stirring over a period of 3 to 4 minutes. To the resulting solution was added 40 grams of para-benzyloxyphenol (0.2 mole). After adding an additional 25 ml. of dioxane, the flask was stoppered and stirred with a mag-mix stirrer until a complete solution resulted. The solution was warmed to gentle refluxing for 2 hours and then allowed to stand at 25°C. for 22 hours. The solvents were removed by evaporation under a hood. The white solid was dissolved in 300 ml. of ether and 150 ml. of water containing 11 grams of sodium hydroxide. The ether layer was separated and the aqueous layer further extracted with two-100 ml. and one-50 ml. portions of ether. Removal of the ether gave 57 grams (86% crude yield) of white solid m.p. 73 to 77°C. Upon recrystallization from 210 ml. of a methanol-ethanol (2 parts methanol and 5 parts ethanol by volume) solution, the compound melted at 86 to 87°C. The aqueous layer was acidified with hydrochloric acid. Upon extraction with ether, 6 grams of para-benzyloxyphenol was recovered. (Analysis of the oxazine: $C_{22}H_{21}NO_2$: Calculated: C 79.73, H 6.39, N 4.22. Found: C 79.68, H 6.29, N, 4.11).

The condensation was repeated under a variety of experimental conditions. The reaction mixture was allowed to stand at room temperature for 40 hours, it was refluxed in dioxane for 3 hours, it was gently refluxed in methanol using 37% aqueous formaldehyde, etc.; in most cases the yields were somewhat lower than the above example.

2-benzylaminomethyl-4-benzyloxyphenol hydrochloride. A 3.6 gram sample of 3,4-dihydro-3-benzyl-6-benzyloxy-1,3,2H-benzoxazine was dissolved in 25 ml. of 95% ethyl alcohol and placed in a round bottom flask equipped with a claissen flask, dropping funnel, and condenser for distillation. After cooling on an ice bath, 2 ml. of 37% aqueous hydrochloric acid was added dropwise through the dropping funnel with shaking. The flask was

gradually warmed until 5 ml. of alcohol distilled over into an alcoholic solution of 2,4-dinitrophenylhydrazine. The distilling flask was cooled and an additional 1 ml. of hydrochloric acid was added. Distillation was repeated until 10 ml. of alcohol distilled over. The residue in the distilling flask was decanted to a beaker, cooled on an ice bath, and approximately 20 ml. of acetone was added. A white solid, 3.4 grams, melting point 168-169°C. was secured. Upon two recrystallizations from 95% ethanol the melting point was 170-171°C. (Analysis: $C_{21}H_{22}ClNO_2$: Calculated: C 70.87, H 6.23, Cl 9.97, N 3.94. Found: C 70.46, H 6.44, Cl 9.95, N 4.02).

The 2,4-dinitrophenylhydrazine solution was acidified with dilute sulfuric acid, warmed to refluxing, and concentrated to one-half volume under the hood. A yellow solid was obtained which did not depress the melting point of an authentic sample of the 2,4-dinitrophenylhydrazone of formaldehyde.

2-benzylaminomethyl-4-benzyloxyphenol. A 4.95 gram sample of 2-benzylaminomethyl-4-benzyloxyphenol hydrochloride was stirred in 150 ml. of water with a mag-mix stirrer. After adding 1.5 ml. of monoethanolamine, the mixture was vigorously stirred for several minutes. The mixture containing a white solid was extracted with several small portions of ether. Upon evaporation of the ether, 4.16 grams of white solid, melting point 83-88°C. was secured. After two recrystallizations from methanol, the sample melted at 90-91°C. A mixed melting point with 3,4-dihydro-3-benzyl-6-benzyloxy-1,3,2H-benzoxazine melted at 70 to 73°C. (Analysis: $C_{21}H_{21}NO_2$: Calculated: C 78.78, H 6.62. Found: C 78.71, H 6.69).

Conversion of 2-benzylaminomethyl-4-benzyloxyphenol to 3,4-dihydro-3-benzyl-6-benzyloxy-1,3,2H-benzoxazine. A 6.39 gram sample of 2-benzylaminomethyl-4-benzyloxyphenol was dissolved in 100 ml. of warm methanol. After cooling on an ice bath, 1.5 ml. of 37% aqueous formaldehyde was added. The solution was shaken for several minutes and a white solid separated. The mixture was gradually warmed to gentle refluxing for two hours. After cooling on an ice bath, the resulting 5.3 grams white solid was removed by filtration and recrystallized from methanol. The solid melted at 85-86°C. and did not depress the melting point of an authentic sample of the oxazine.

2-benzylaminomethyl-hydroquinone hydrochloride. An 8.8 gram sample of 2-benzylaminomethyl-4-benzyloxyphenol hydrochloride was placed in a round bottom flask with 15 ml. of 37% aqueous hydrochloric acid. After attaching to a reflux condenser the mixture was warmed on a boiling water bath for 30 minutes. An oil formed. The mixture was cooled on an ice bath. A white solid was removed by filtration and washed with several small portions of ether. After drying, the solid weighed 5.1 grams. It was recrystallized from isopropyl alcohol, melting point 177-178°C. (Analysis: $C_{14}H_{16}ClNO_2$: Calculated: C 63.27, H 6.06. Found: C 63.49, H 5.90).

The ether was separated from the aqueous layer. Upon removal of the ether, 1.1 grams of benzyl chloride,

boiling point 178-180°C. was secured.

2-benzylaminomethyl-hydroquinone. The above experiment was repeated using 21.8 grams of 2-benzylaminomethyl-4-benzyloxyphenol hydrochloride and 25 ml. of aqueous hydrochloric acid. A solid did not form. After extracting the aqueous layer with ether to remove the benzylchloride, it was saturated with potassium bicarbonate and extracted with several small portions of ether. Removal of the ether gave 7.9 grams of the free base, melting point 115-117°C. Upon three recrystallizations from benzene the solid melted at 120-120.5°C. (Analysis: $C_{14}H_{15}NO_2$: Calculated: C 73.34, H 6.59, N 6.11. Found: C 73.53, H 6.52, N 6.11).

Conversion of Hydroquinonemonobenzylether to Hydroquinone. Three grams of hydroquinone monobenzylether was placed in a round bottom flask with 10 ml. concentrated hydrochloric acid and the mixture warmed at 85-90° under a reflux condenser for 45 minutes. The ether gradually changed to a brown oil and finally nearly a clear solution resulted. The flask was cooled and an additional 10 ml. conc. hydrochloric acid was added. The mixture was warmed for 1 hour at 85-90°, cooled to room temperature, made basic with sodium hydroxide, and extracted with one-20 ml. and two-10 ml. portions of ether. The ether was allowed to evaporate leaving a nearly colorless liquid, which was identified as benzyl chloride, boiling point 180-181°C. at 759 mm.; quaternary ammonium salt with N,N-dimethylaniline gave a melting point of 109-111°C.

The aqueous extracts were made acidic with hydrochloric acid and extracted with one-30 ml. and two-20 ml. portions of ether, which upon evaporation gave 170 g. of brownish white solid, m.p. 105-140°. The solid was recrystallized from tertiary butyl alcohol giving 1.5 g. white solid m.p. 165-170°. An additional recrystallization gave m.p. 169-171°; mixed m.p. with hydroquinone showed no depression.

3,4-dihydro-3-benzyl-6-hydroxy-1,3,2H-benzoxazine. The Mannich base 2-benzylaminomethyl-4-hydroxy phenol was readily converted to the oxazine under conditions to those described for conversion of 2-benzylaminomethyl-4-benzyloxyphenol to its corresponding oxazine as indicated above in 91.5% yield, melting point 105-106° after three recrystallizations from carbon tetrachloride. (Analysis: $C_{15}H_{15}NO_2$: Calculated: C 74.66, H 6.26, N 5.80. Found: C 75.04, H 6.44, N 5.79).

Condensation of para-benzyloxyphenol, formaldehyde, and dibenzylamine. To 1.87 ml. of 37% aqueous formaldehyde (0.025 mole) in 50 ml. of methanol was added dropwise with mag-mix stirring and cooling on an ice bath 4.93 grams (0.025 mole) of dibenzylamine. After adding 5 grams (0.025 mole) para-benzyloxyphenol, the solution was refluxed for 3 hours. The solvents were removed under a hood; the residue was dissolved in 100 ml. ether and 100 ml. water containing 5.6 grams (0.1 mole) of potassium hydroxide. The aqueous extract was further extracted with two 35 ml. portions of ether. The combined ether extracts upon evaporation under the hood gave 4.87 grams (96% yield) of tetrabenzyldiaminomethane, melting point 91-93°. Upon recrystallization

from 95% ethanol the melting point was 97-98°C. (literature value 99-101°C.) (Analysis: $C_{29}H_{30}N_2$: Calculated: C 85.70, H 7.44, N 6.90. Found: C 86.04, H 7.25, N 7.07).

Condensation of hydroquinone, formaldehyde, and dibenzylamine. Dibenzylamine (9.86 grams; 0.05 mole), formaldehyde (3.75 ml. 37%; 0.05 mole), and hydroquinone (2.75 grams; 0.025 mole) in 50 ml. of methanol were condensed as for para-benzyloxyphenol above. An essential quantitative yield of tetrabenzyldiaminomethane was isolated.

When dimethylamine was used in lieu of the dibenzylamine, yields in excess of 75% of 2,5-bis(dimethylaminomethyl)hydroquinone (melting point 190-191°; literature value 190°) were readily obtained. Condensation of equal mole quantities of dimethylamine, formaldehyde, and hydroquinone gave a product which did not depress the melting point of the 2,5-derivative.

Condensation of tetrabenzyldiaminomethane with formaldehyde and para-benzyloxyphenol. Tetrabenzyldiamonomethane (10.15 grams, 0.025 mole), formaldehyde (1.87 ml. 37%; 0.025 mole), and para-benzyloxyphenol (10 gram; 0.025 mole) in 50 ml. of methanol was refluxed for 3 hours. The solvents were removed under a hood. The resulting mixture was dissolved in 100 ml. water containing 2.8 gram of potassium hydroxide (0.05 mole) and 100 ml. ether. The ether was removed and the aqueous layer further extracted with two small portions of ether. Removal of the ether under the hood gave a nearly quantitative recovery of the tetrabenzyldiaminomethane. Acidification of the aqueous layer with hydrochloric acid followed by three extractions with small portions of ether gave 10 grams, quantitative recovery of the para-benzyloxyphenol.

Condensation of benzylamine, formaldehyde, and hydroquinone. Benzyl amine (11 ml., 0.1 mole), formaldehyde (7.5 ml., 37%, 0.1 mole), and hydroquinone (11 g., 0.1 mole) in 75 ml. of methanol was refluxed for 2 hours. The solvents were removed under the hood. The resulting mixture was extracted with ether and 100 ml. of water containing 10 grams of sodium hydroxide. The ether extracts were treated with 37% aqueous hydrochloric acid. Upon standing a nearly quantitative recovery of the amine as its hydrochloride salt was secured.

Repetition of the experiment using benzylamine hydrochloride in lieu of the free base gave similar results.

Summary

Dibenzylamine, formaldehyde, and para-benzyloxyphenol or hydroquinone did not undergo a Mannich condensation under conditions similar to the condensation of dimethylamine, formaldehyde, and hydroquinone which gave high yields of 2,5-bis(dimethylaminomethyl)hydroquinone. Benzylamine and formaldehyde in 1:1 mole ratio condensations failed to give Mannich bases with hydroquinone or para-benzyloxyphenol. Condensations of benzylamine and formaldehyde in a 1:2 mole ratio with these phenolic compounds gave 1,3,2H-benzoxazines. Reaction of benzylamine, formaldehyde, and hydroquinone in a 1:2:1 mole ratio gave two isomeric bis benzoxazines instead of the expected mono 3,4-

dihydro-3-benzyl-6-hydroxyl-1,3,2H-benzoxazine. An indirect synthesis of the latter compound was reported.

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EARLY GROWTH OF LOBLOLLY AND SHORTLEAF PINE AT VARIOUS SPACINGS IN SOUTHERN ILLINOIS

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Past practices on land cleared for agriculture in southern Illinois have reduced the quality of many sites to the point where the valuable native hardwood species cannot be successfully grown. Hence it has been necessary to find less demanding species to reforest these degraded sites. Shortleaf pine (*Pinus echinata* Mill.) and loblolly pine (*Pinus taeda* L.) have been widely planted in this area, which is at the limit or north of their present natural ranges. The results of an experiment to study the effect of spacing on the growth and yield of shortleaf and loblolly pine planted on a site of medium quality are presented in this paper. The work was done at the Dixon Springs Experiment Station in Pope County.

Methods

Four replications of loblolly pine, and three of shortleaf pine, were planted at spacings of 4 x 4, 6 x 6, 8 x 8, and 10 x 10 feet in the spring of 1949. Plots were one-half acre in size, with a 33-foot isolation strip, and were laid out in a randomized block design. Seedlings were grown at the Union State Tree Nursery, Jonesboro, Illinois. Not much is known about seed source. Nursery records indicate that the loblolly pine was grown from seed obtained in north Alabama or Maryland, while the source of the shortleaf seed was unknown. However, at that time the State Division of Forestry attempted to procure seed from as far north in the range of both species as possible.

Survival counts were made at the end of the first, second, third, eleventh, and thirteenth growing seasons. Diameter and height measurements were made during the fall of 1959 and 1961, when the plantations were 11 and 13 years old.

Local volume tables were constructed for each species and spacing, using the variable-square method described by Spurr (1952). Volumes are for peeled wood and include the entire bole of the tree.

Site Description

At planting time the site had been abandoned from cultivation for about ten years. There was a well-established ground cover of broomsedge (*Andropogon* spp.) where erosion was slight to moderate, while tickle grass (*Aristida dichotoma* Michx. and *Danthonia spicata* (L.) Beauv.) was dominant on severely eroded areas.

The soil belongs to the Grantsburg series. These are Gray-Brown Podzolic, intergrading with Red-Yellow Podzolic soils, that were developed under forest cover from loess (80 inches or less in depth) over a predominantly sandstone bedrock. When uneroded, soil texture varies from a silt loam in the A horizon to

a silty clay loam in the B horizon. A moderately well-developed silt pan (fragipan) occurs in the upper part of the C horizon. The pan is compact, coarse-blocky to structureless, and impedes both root penetration and the downward movement of moisture. These soils are reasonably well-supplied with available potassium but are low in phosphorous, nitrogen, and organic matter.

Moisture conditions were favorable during 1949, 1950, and 1951. Drought conditions of varying intensities prevailed in 1952, 1953, and 1954. The planation was subjected to extreme cold in the winter of 1950-51 and heavy glaze storms in 1950 and 1952 (Boggess and McMillan, 1954).

Results

Early survival was better than 95 percent. After 13 growing seasons survival was 95 percent or better for all spacings except the 4 x 4-foot shortleaf pine, which was 82 percent. Current mortality is heaviest in the 4 x 4-foot spacings and is greater for shortleaf than for loblolly pine.

Spacing has had little effect on the total height of either species, but tree diameters were larger at the wider spacings (Table 1). Loblolly pine averaged about six feet more in height than shortleaf pine.

The differences in wood volume produced by shortleaf pine at the various spacings were statistically significant (one-percent level) when all trees were considered. On the basis of trees four inches and over in diameter, there was no significant difference between the 4 x 4- and 8 x 8-foot spacings, but all other comparisons were significant. In loblolly pine there were no significant differences between the 6 x 6- and 8 x 8-foot spacings, while the other spacings differed significantly. This was true for all trees as well as for those four inches in diameter and above.

Table 1.—Average Height and Diameter of Loblolly Pine and Shortleaf Pine.

Spacing, feet	Loblolly pine				Shortleaf pine			
	Height	Std. error	DBH	Std. error	Height	Std. error	DBH	Std. error
	Feet		Inches		Feet		Inches	
4 x 4	30.2	0.2	3.5	0.0	24.6	0.3	3.2	0.0
6 x 6	32.4	0.5	4.8	0.1	25.1	0.6	4.3	0.1
8 x 8	34.4	0.8	6.0	0.1	23.9	0.5	4.8	0.1
10 x 10	32.2	1.0	6.4	0.1	23.6	0.5	5.3	0.1

TABLE 2.—Number of Trees, Basal Area, and Cubic-Foot Volume Per Acre of Shortleaf Pine.

DBH	Spacing, feet											
	4x4	6x6	8x8	10x10	4x4	6x6	8x8	10x10	4x4	6x6	8x8	10x10
	Number of trees				Basal area, square feet				Volume, cubic feet			
0	4				0.01				0.35			
1	141	20			1.11	0.15	0.06		12.44	1.72	0.43	
2	396	53	14	6	9.96	1.34	0.30	0.18	88.63	12.27	2.93	1.40
3	862	187	56	39	43.22	10.41	3.23	2.12	388.75	84.37	25.58	18.07
4	712	377	177	54	60.11	33.83	15.73	4.98	676.39	354.07	175.12	42.40
5	104	377	216	133	12.99	51.06	30.21	19.91	181.04	542.40	332.14	162.02
6	9	80	142	127	1.64	15.36	27.06	24.85	23.52	195.92	313.09	273.57
7	9	7	28	35	2.60	1.99	7.35	9.57	31.88	22.10	85.11	103.27
8		3	4	9		1.11	1.12	1.03		16.74	16.65	40.21
Total, all trees	2,237	1,104	637	403	131.64	115.25	85.06	62.64	1,403.00	1,229.59	951.05	640.94
Total, 4″ or more DBH	834	844	567	358	77.34	103.35	81.47	60.34	912.83	1,131.23	922.11	621.47

TABLE 3.—Number of Trees, Basal Area, and Cubic-Foot Volume Per Acre of Loblolly Pine.

DBH	Spacing, feet											
	4x4	6x6	8x8	10x10	4x4	6x6	8x8	10x10	4x4	6x6	8x8	10x10
	Number of trees				Basal area, square feet				Volume, cubic feet			
1	8	2	.....	4	0.28	0.03	.....	0.03	4.25	0.03	.....	0.86
2	318	25	3	4	8.60	0.46	0.06	0.13	89.98	5.05	0.82	1.60
3	926	95	8	2	48.33	5.20	0.40	0.11	586.80	47.60	5.05	1.38
4	935	275	26	16	82.33	25.79	2.49	1.44	997.62	199.38	28.95	15.34
5	214	462	165	54	27.33	64.98	23.31	7.76	347.83	811.69	320.94	91.53
6	19	230	290	126	3.40	43.84	59.14	25.89	50.40	683.79	806.80	304.66
7	.....	30	141	142	.....	7.48	36.54	38.26	.....	121.80	531.65	530.54
8	.....	.....	16	51	.....	.....	5.48	17.67	.....	.....	67.29	246.69
9	.....	.....	5	2	.....	.....	2.30	1.00	.....	.....	37.68	15.36
Total, all trees	2,420	1,119	654	401	170.27	147.78	129.72	92.29	2,076.88	1,869.34	1,799.18	1,207.96
Total, 4″ or more DBH	1,168	997	643	391	113.06	142.09	129.26	92.02	6,395.85	1,816.66	1,793.31	1,204.12

Loblolly pine produced significantly more basal area and volume (one-percent level) at each spacing than did shortleaf pine (Tables 2 and 3). Shortleaf pine volume was 68 percent that of loblolly pine on the 4 x 4-, 66 percent on the 6 x 6-, and 53 percent on the 8 x 8- and 10 x 10-foot spacings. None of the observed differences could be attributed to site (block effect) on the basis of statistical analysis.

During the past two growing seasons, the percentage increase in volume has been greater at each spacing for shortleaf pine than for loblolly pine (Fig. 1). In actual volume, however, shortleaf pine growth exceeded loblolly pine only on the 4 x 4-foot spacing.

Discussion

As previously mentioned, differences in site quality were not a factor in determining the superior growth of loblolly pine over shortleaf pine. This is further emphasized by comparing the best shortleaf plot with the poorest loblolly plot on which shortleaf pine yields are only 64, 62, 58, and 54 percent as great

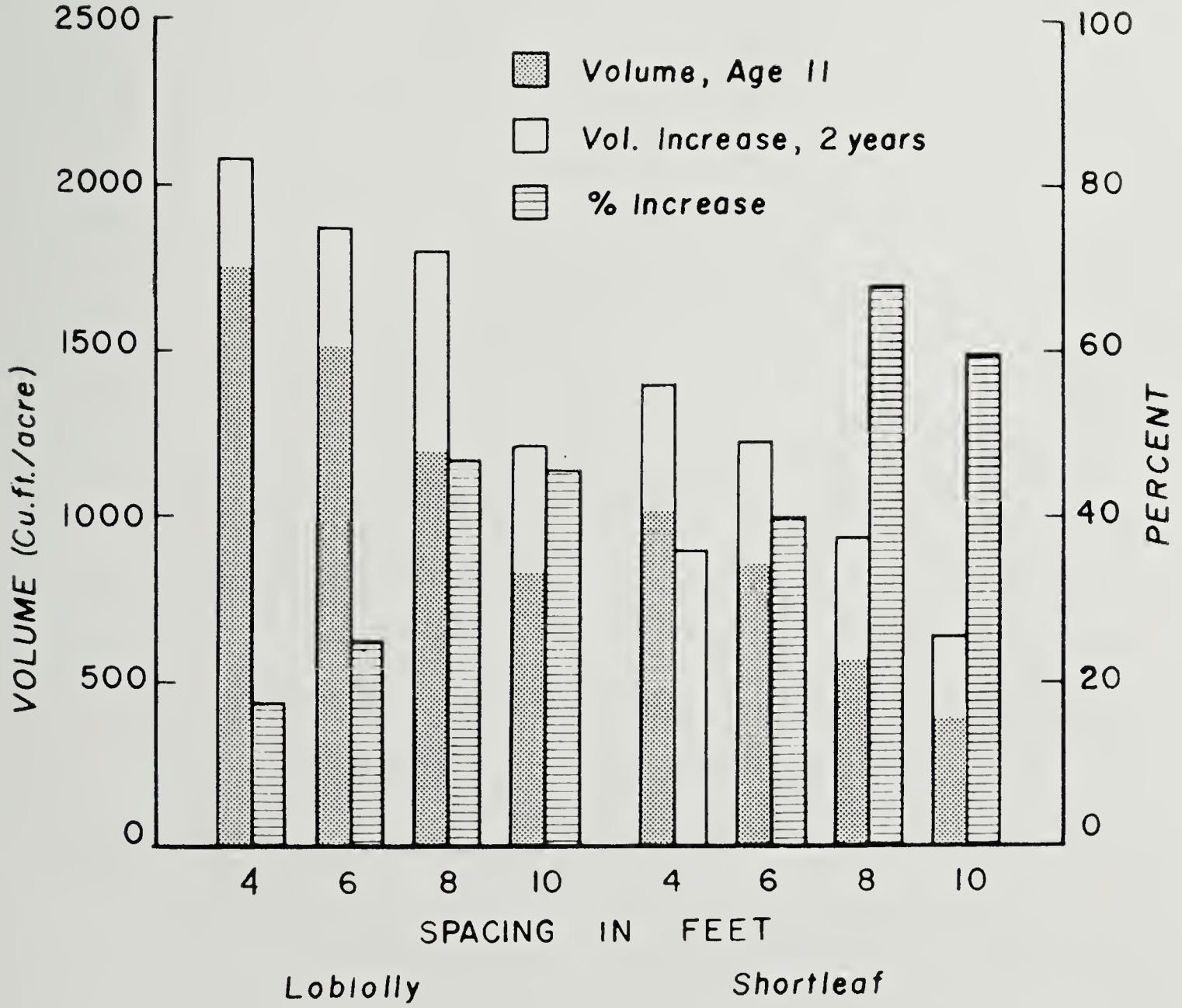

Fig. 1.—Total volume per acre and per-centage increase during past two years.

as those of loblolly pine for the 4-, 6-, 8-, and 10-foot spacings, respectively.

We recognize that seed source could be an important factor in the growth differential between these two species and that in this case it is relatively unknown. However, other workers have reported superior growth of loblolly pine as compared to shortleaf when the two species are associated (Coile, 1948; Mann, 1953; Zahner, 1957; Williston, 1959). Our results confirm that this holds true in early plantation growth considerably north of the natural range of loblolly pine and at the northern limit of shortleaf pine in the Central States area.

The percentage volume increase during the past two years, when considered along with actual volume, gives some indications of the most desirable spacing for planting loblolly pine on medium quality sites in this area (Fig. 1). The percentage increase on the 4 x 4-foot spacing is about one-third, and the 6 x 6- about one-half, that of the two widest spacings. Then, too, the growth on the 4 x 4-foot spacing is being put on small trees, as only 67 percent of the volume is in trees four inches and above in diameter as compared with 97 percent and above on the 6 x 6-, 8 x 8-, and 10 x 10-foot spacings. While it is silviculturally desirable to thin the 4 x 4-foot spacing, a commercial thinning for pulpwood is not feasible because of the small tree size. The same is probably true for the 6 x 6-foot spacings. In contrast the two wider spacings are growing at a highly satisfactory rate, and a thinning now would be premature.

When all factors such as size, percent of live crown present, volume, and growth rate are considered, we believe that the most desirable spacing to plant loblolly pine lies between the 6 x 6- and the 8 x 8-foot spacing with the first thinning between ages 17 and 20. The shortleaf pine has not yet reached a point where such recommendations are indicated.

Comparisons of stocking, basal area, average diameter, and height of the Illinois plantations with that reported for spacing studies in 14-year-old loblolly pine at Auburn, Alabama (Ware and Stahelin, 1948); 14-year-old loblolly and shortleaf pine at Athens, Georgia (Jackson, 1958); and 11-year-old loblolly pine growing on a medium quality site in the Georgia Piedmont (Hamilton, 1956) are shown in Table 4. Loblolly pine in Illinois compares favorably, in all respects, with the 11-year-old, medium site, Georgia plantations. Considering the one-year age differences, the same holds true in comparing the Illinois loblolly pine and shortleaf pine with the older plantations in Alabama and Georgia.

The results of this study, although involving but 13 years of growth, emphasize the superior growth of loblolly pine as compared with shortleaf pine in southern Illinois. It also shows that the growth of both species, and loblolly pine in particular, compares favorably at this point with that reported for the same species in the southern states. There is some element of risk, due to the susceptibility of loblolly pine to glaze damage, in planting this species (Boggess and McMillan, 1954).

TABLE 4.—Comparison of Loblolly Pine and Shortleaf Pine Growth in Illinois, Alabama, and Georgia.

Location	Spacing, feet															
	4x4	6x6	8x8	10x10	4x4	6x6	8x8	10x10	4x4	6x6	8x8	10x10	4x4	6x6	8x8	10x10
	Number of trees per acre				Basal area, sq. ft./acre				Average diameter, in.				Average height, ft.			
	Loblolly pine															
Illinois[1]	2,497	1,131	654	410	155	127	106	71	3.4	4.5	5.5	5.6	.....			
Illinois[2]	2,420	1,119	654	401	170	148	130	92	3.5	4.8	6.0	6.4	30.2	32.4	34.4	32.2
Georgia[1]	2,360	1,190	720	.....	116	114	139	.....	2.8	4.1	5.5	.....	22.0	24.0	24.0	.....
Georgia[3]	2,143	1,070	634	.....	170	136	108	.....	3.3	4.8	5.6	.....	.....			
Alabama[3]	1,904	982	566	418[4]	142	134	116	91[4]	3.7	5.0	6.1	6.3[4]	.....			
	Shortleaf pine															
Illinois[2]	2,237	1,104	637	403	132	115	85	63	3.2	4.3	4.8	5.3	24.6	25.1	23.9	23.6
Georgia[3]	2,348	1,116	648	.....	131	94	79	.....	3.2	3.9	4.7	.....	.....			

[1] Eleven years after planting.
[2] Thirteen years after planting.
[3] Fourteen years after planting.
[4] Spacing was 9.6 x 9.6 feet.

Recent development of pulpwood markets within the area may help offset this disadvantage by providing an outlet for salvage materials.

Summary

1. Loblolly pine (*Pinus taeda* L.) and shortleaf pine (*Pinus echinata* L.) were planted at spacings of 4 x 4-, 6 x 6-, 8 x 8-, and 10 x 10-feet on a site of medium quality in southern Illinois. Growth and yield data were collected at the end of the eleventh and thirteenth growing seasons.

2. Spacing had little effect on tree heights, but diameters were larger at the wider spacings.

3. Loblolly was taller, larger in diameter, and produced significantly more wood than shortleaf pine at each spacing. Spacings between 6 x 6- and 8 x 8-feet are suggested for planting loblolly pine, but present results do not yet warrant similar recommendations for shortleaf pine.

4. Growth and yield of both species compare favorably with that reported for similar studies in the Piedmont Region of Alabama and Georgia.

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SYNTHESIS OF AMINOGUANIDINE-C^{14}

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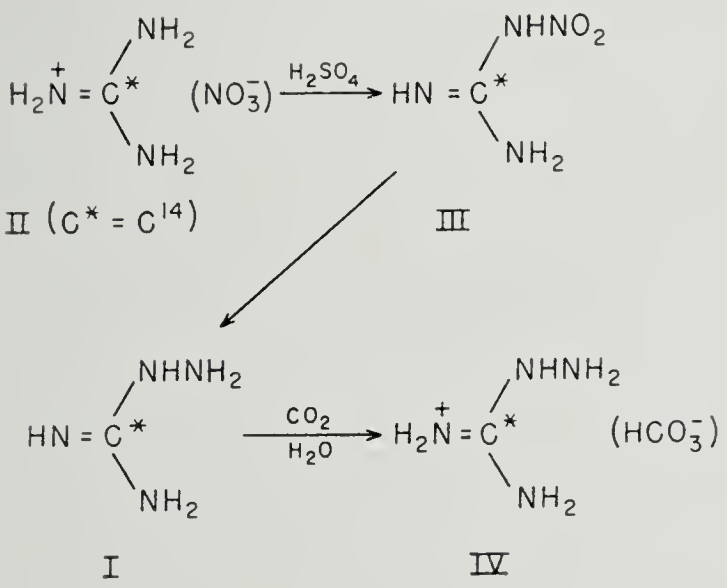
This investigation reports the synthesis of aminoguanidine-C^{14} (I) used as a tracer in studying its physiologic effects in animals. The starting material for the synthesis comprised guanidine-C^{14} nitrate (II) which was converted to nitroguanidine-C^{14} (III) by reaction in sulfuric acid followed by catalytic reduction (Lieber and Smith, 1936) and precipitation as aminoguanidine-C^{14} bicarbonate (IV) by carbonate ion (Thiele, 1898). All intermediate active substances were isolated to serve as references for analysis by paper chromatography and isotope activity. The objective of the synthesis was to prepare IV with a specific activity of approximately 1 μ c/mg.



Experimental

Aminoguanidine-C^{14} bicarbonate (IV). Previously chilled concentrated sulfuric acid, 1.2 ml, was placed in a 3 ml reaction container, kept in an ice-bath for the duration of the reaction. A mixture of 73.0 mg of II and 395 mg of unlabeled guanidine nitrate was added very slowly over 90 minutes to the sulfuric acid with constant stirring, maintaining the temperature below 20°. The mixture was allowed to stand overnight at room temperature followed by addition of 10 g of crushed ice. After one hour, the white precipitate was collected by suction filtration. The solvent was evaporated under high vacuum and precipitation effected by the addition of 10 g of crushed ice giving a small additional amount of III. The combined precipitate was redissolved in 5 ml of boiling water yielding III, by standing overnight, as fine long needles. The product was collected by suction filtration and the mother liquor evaporated to dryness, recrystallization giving additional III. The mother liquor was analysed for activity before every such recovery. A 477 μ g sample of III was retained for analysis, the remaining 320 mg of III being used for the succeeding step. The 320 mg of III was transferred into a 500 ml centrifuge bottle together with 4 ml of fifteen per cent acetic acid, 10 ml of water and 50 mg of platinum oxide catalyst. The hydrogen uptake was stoichiometric after 150 minutes on a mechanical shaker. The catalyst was

filtered off and washed with a few drops of cold water. Sodium bicarbonate, 1.5 g, was added to the combined filtrates and the resulting solution maintained in the refrigerator overnight. The white precipitate of IV was recovered by suction filtration, washed twice with 2 ml of cold water, twice with 2 ml of ethanol, and once with 2 ml of dry ether and finally, air-dried. The resulting white material had a decomposition point of 171-172° similar to that of unlabeled aminoguanidine bicarbonate as prepared by the method of Thiele. The yield was 325 mg of III, 54.1 percent.

Analysis. All the labeled and unlabeled compounds involved were identified for their chemical and isotope purity by paper chromatograph and for specific activity. Both methods gave exact checks for identity. The activity peaks obtained on the radiological chromatograph on the C^{14} compounds corresponded to the spots on the chromatograms when analysed chemically. The chromatograms were scanned at a speed of ¾-inch per minute, at 900 volts and 3,000 counts per minute. Standard was carried out with unlabeled-guanidine nitrate, 1.467 mg; nitroguanidine, 1.055 mg, and; aminoguanidine bicarbonate, 1.759 mg, respectively. Each sample was dissolved in saline solution (1 ml). The three compounds were then spotted on 1½-inch Whatman Paper No. 1 and developed in a chromatography chamber using a mixture of 1-butanol (60 ml), acetic acid (15 ml) and water (25 ml) for development. After the chromatograms were developed and dried, they were dipped in ferricyanide reagent. The *reagent* was prepared from equal volumes of 10 percent potassium ferricyanide and 10 percent sodium hydroxide diluted with nine volumes of water. Before using the reagent was mixed with an equal volume of acetone. Reddish-orange spots were obtained from which the R_f values were calculated. The data obtained are summarized in Table 1. The paper

TABLE 1.—Paper Chromatography on Unlabeled Compounds[a].

Sample	g/ml	Am't Spotted ∂	Am't of Sample γ	R^f x 100 Value
1. Guanidine Nitrate	1.467	10	14.7	50
2. Guanidine Nitrate	1.467	20	29.4	50
3. Nitroguanidine	1.055	10	10.5	57
4. Nitroguanidine	1.055	10	21.0	57
5. Aminoguanidine Bicarbonate	1.759	10	17.6	52
6. Aminoguanidine Bicarbonate	1.759	20	35.2	52

a Results of duplicate independent runs.

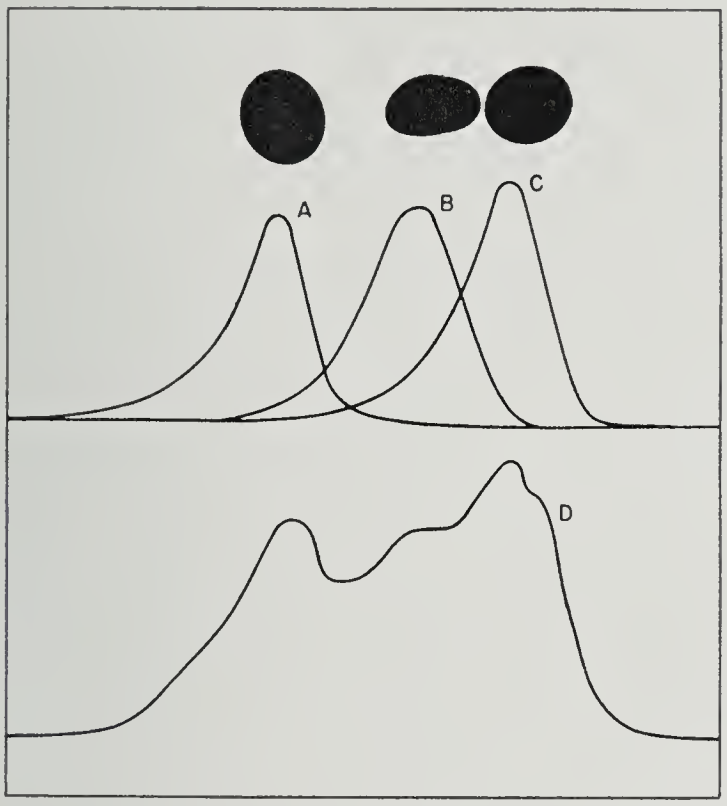


FIG. 1.—Autoradiogram traces and chemical identification of chromatograms: (A), guanidine -C^{14} nitrate; (B), nitroguanidine -C^{14}; (C), aminoguanidine -C^{14} bicarbonate; and (D), mixture of all three simultaneously.

chromatography on the C^{14}-compounds was performed in exactly the same manner, the only difference being that the C^{14}-labeled chromatograms were first scanned by the chromatograph. Curves with activity peaks were recorded on the locations where the labeled compounds were present. The chromatograms were identified for isotope purity as well as composition against the known unlabeled standard chromatograms. The chromatograms scanned on the Forro chromatograph showed the location of the particular compound on each strip. One curve was obtained for each substance (Figure No. 1) in order to confirm isotope purity and to mark the location on the chromatogram. The labeled chromatograms were then dipped in ferricyanide reagent. Reddish-orange spots appeared in identical

TABLE 2.—Paper Chromatography on C^{14}-Labeled Compounds.

Sample	g/ml	Am't Spotted ∂	Am't of Sample γ	R^f x 100 Value
Guanidine C^{14}—Nitrate	497	10	4.97	50
Guanidine C^{14}—Nitrate	497	10	4.97	50
Nitroguanidine C^{14}	477	50	23.85	57
Nitroguanidine C^{14}	477	50	23.85	57
Aminoguanidine C^{14}—[a]	577	50	28.85	52
Aminoguanidine C^{14}—	577	50	28.85	52
Guanidine C^{14}—Nitrate[b]	497	10	4.97	
Nitroguanidine C^{14}	477	50	23.85	50-57
Aminoguanidine C^{14}	577	50	28.85	
Guanidine C^{14}—Nitrate[b]	497	10	4.97	
Nitroguanidine C^{14}	477	50	23.85	50-57
Aminoguanidine C^{14}	577	50	28.85	

a Aminoguanidine C^{14} was used as the bicarbonate.
b A mixture of all three compounds were spotted on one chromatogram simultaneously.

TABLE 3.—Activity Analysis on C^{14}-Labeled Compounds.

Sample	Am't Used ∂	Dilution Factor	NCPM	μc/ml	μc/mg	Ave. μc/mg	Ave. μc/mM
Background.....	0	0	20	0	0	0	0
Background.....	0	0	20	0	0	0	0
Benzoic Acid C^{14}— Standard.....	100	1.0	940	0.00111	.....	.....	.....
Benzoic Acid C^{14}— Standard.....	100	1.0	940	0.00111	.....	.....	.....
Guanidine C^{14}— Nitrate.....	10	100	32190	4.125	8.032	8.032	1.000
Guanidine C^{14}— Nitrate.....	10	100	32180	4.125	8.032		
Nitroguanidine C^{14}.	20	50	1420	0.903	1.935		
Nitroguanidine C^{14}.	20	50	1420	0.903	1.935	1.937	0.200
Nitroguanidine C^{14}.	50	20	3600	0.910	1.940		
Nitroguanidine C^{14}.	50	20	3580	0.909	1.939		
Aminoguanidine C^{14} —Bicarbonate...	20	50	1030	0.675	1.433		
Aminoguanidine C^{14} —Bicarbonate...	20	50	1040	0.678	1.435	1.433	0.195
Aminoguanidine C^{14} —Bicarbonate...	50	20	2480	0.669	1.430		
Aminoguanidine C^{14} —Bicarbonate...	50	20	2640	0.671	1.432		

places where the activity peaks had been previously recorded. Both the spots and the peaks corresponded to the reddish-orange spots obtained in the unlabeled compounds. Table 2 summarizes the R_f values found for the C^{14}-labeled compounds. The *activity analysis* of all three of the C^{14}-labeled compounds are summarized in Table 3. The counts were compared with a benzoic acid C^{14} standard.

Acknowledgment

The authors gratefully acknowledge the suport of these studies by a grant from the National Science Foundation (NSF-G 11276).

Summary

Aminoguanidine-C^{14} bicarbonate has been synthesized with a specific activity of 1.433 microcuries per milligram or 0.195 microcuries per millimole by conversion of guanidine-C^{14} nitrate to nitroguanidine-C^{14} and subsequent reduction to aminoguanidine-C^{14} by catalytic hydrogenation.

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EFFECT OF GLYCINE ON THE GROWTH IN ASEPTIC CULTURE OF HEALTHY AND AMPELAMUS-VIRUS-INFECTED TISSUE OF *NICOTIANA GLUTINOSA* L.

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Preliminary studies indicated that cultures of stem callus tissue from healthy *Nicotiana glutinosa* L. tolerated concentrations of glycine (amino acetic acid) greater than 3 mg/liter; the amount generally recommended (White, P. R., 1939 and 1943 and Hildebrandt, A. C. *et al.*, 1946). Since radioactive glycine affords a means of introducing tagged carbon and nitrogen or tritium into metabolites of healthy and virus-infected tissue, it seemed worthwhile to determine on chemically defined media the concentration of glycine for maximal growth rate of healthy and diseased callus tissue in aseptic culture. This paper reports the results of the experiments and compares some methods of measuring the growth rate of callus tissue in aseptic culture.

Materials and Methods

Culture Media. Two basic media were used: (W) White's medium (White, P. R., 1943) modified according to other media (Bonner, J., 1940, Gautheret, R., 1939, and Heller, R., 1953) and (H) Hildebrandt's medium (Hildebrandt, A. C. *et al.*, 1946) formulated for the culture of tobacco tissue. Composition of the two media depicted in Table 1 is given, when possible, in molarity to avoid confusion about water of crystallization in some chemicals.

Tissue Cultures. Cultures of callus tissue of *N. glutinosa* were derived from stems of healthy plants and plants infected with Ampelamus virus (an unidentified virus originally isolated from *Ampelamus albidus* (Nutt.) Britt. 1894 and presumably a strain of cucumber mosaic virus or of tobacco ring-spot virus). Tissue subcultures were made by transferring a "loopful," about 20 mg of "transferendum," of a typical culture into 125 ml screw cap Erlenmeyer flasks containing 40 ml of 0.6% agar (W) or (H) medium (see Table 1). "Transferendum," plural "transferenda," (a new term, coined in collaboration with J. L. Heller, Department of Classics, University of Illinois, meaning the material transferred from one container to another container) is used herein to avoid ambiguity of the terms "inoculum," "explant," or "transplant" in this particular frame of reference.

Cleaning of Glassware. Glassware was cleaned following a procedure involving four steps:

1. Soaking in aqua regia (3 parts HCl and 1 part HNO_3) at room temperature for at least 16 hours.
2. Rinsing with tap water to remove aqua regia.

TABLE 1.—Constituents and amounts in the two media. (W) modified White medium and (H) Hildebrandt *et al.* medium.

Constituent	Molarity of medium	
	(W) White:	(H) Hildebrandt:
Carbon source:		
Sucrose	6.0×10^{-2}	6.0×10^{-2}
Vitamins etc.:		
Cysteine HC1	6.3×10^{-5}	
Thiamine HC1	3.0×10^{-7}	
Nicotinic acid	4.0×10^{-6}	
Pyridoxine HC1	4.9×10^{-7}	
Minerals:		
$AlCl_3$	4.8×10^{-7}	
$Ca(NO_3)_2$	1.2×10^{-3}	2.5×10^{-3}
$CuSO_4$	1.2×10^{-7}	
$Fe_2(C_4H_4O_6)_3$	2.6×10^{-6}	6.1×10^{-5}
H_3BO_3	2.4×10^{-5}	5.0×10^{-6}
KCl	9.0×10^{-4}	9.0×10^{-4}
KI	4.5×10^{-6}	1.8×10^{-5}
KNO	8.0×10^{-4}	8.0×10^{-4}
$MgSO_4$	3.0×10^{-3}	7.4×10^{-4}
$MnSO_4$	3.0×10^{-5}	3.0×10^{-5}
NaH_2PO_4	1.4×10^{-4}	2.7×10^{-4}
Na_2SO_4	1.4×10^{-3}	5.6×10^{-3}
$ZnSO_4$	9.4×10^{-6}	2.0×10^{-5}
Other:		
Coconut milk	(15%)	(15%)
Agar	(0.6%)	(0.6%)
Water[a] to final volume	(1,000 ml)	(1,000 ml)
H-ion concentration	(pH5.6-5.8)	(pH5.6-5.8)
Total molarity, medium ($\times 10^{-3}$)	67.57889	70.944
Total molarity, vitamins ($\times 10^{-5}$)	6.827	
Total molarity, minerals ($\times 10^{-3}$)	7.51052	10.944

a Water, distilled and deionized.

3. Boiling in a solution of detergent in distilled water.
4. Rinsing with distilled water then with distilled-deionized water and drying in an inverted position.

Growth Rate Measurements. The growth was estimated by three types of measurements: wet weight, volume, and total nitrogen. *Wet weight* of callus tissue was determined by weighing the cultures separately in closed weighing bottles. *Volume* of the cultures was ascertained by measuring the volume of liquid displaced when the culture was submerged in a reservoir of fluid (25% aqueous ethanol) contained in a mi-

TABLE 2.—Effect of concentration of glycine on growth as measured by wet weight of healthy and Ameplamus-virus-infected cultures of *Nicotiana glutinosa* callus tissue in two basic media: (W) and (H).

Glycine, molarity	(W) Medium		(H) Medium	
	Healthy tissue	Diseased tissue	Healthy tissue	Diseased tissue
.00004	1.438[a] (100[b])	0.000	2.827(65)	1.116(71)
.0004	2.383(4)	0.000	2.331(3)	0.977(38)
.004	2.073(100)	0.000	2.376(37)	0.917(39)
.04	0.074(40)	0.000	0.060(39)	0.751(25)
.046	1.015(82)	0.000	0.061(16)	0.352(71)

a Mean wet weight in grams of four cultures incubated for 35 days at 26° C in one experiment.
b Coefficient of variability of the mean, percentage.

crovolumeter to be described in a forthcoming paper. *Total nitrogen* in a culture was determined spectrophotometrically at 450mμ by the Hoffman and Osgood modification of the microKjeldahl method (Hoffman, W. S., and B. Osgood, 1940). A standard nitrogen curve was constructed from nitrogen determinations made on solutions of ammonium sulfate containing 0.025, 0.015, and 0.0075 mg N/ml.

Virus Assay. Ampelamus virus was assayed on primary leaves of *Vigna sinensis* Endl., Table Cowpea, California Blackeye, by mechanical inoculation with extract containing 7% abrasive powder (800 mesh silicon carbide).

Experiments and Results

To determine the concentration of glycine necessary for maximal growth of healthy and of virus-infected *N. glutinosa* callus tissue in aseptic culture, transferendum of the two types of tissues were introduced into flasks containing (W) medium and (H) medium, respectively. Concentration of glycine in the culture flasks varied from 4 x 10^{-5}M to 4.6 x 10^{-2} molarity. The subcultures were incubated for 35 days at 26 ± 1° C and 60 ± 2% relative humidity. Four subcultures were used for each test.

The results given in Table 2 and Figure 1 indicate that healthy and virus-infected tissue differed in their response to the concentration of glycine contained in the two media. Growth rates of the healthy tissue on the two media were similar at all concentrations of glycine except 4 x 10^{-5}M. The significance of this difference is doubtful. Growth was retarded at 4 and 4.6 x 10^{-2}M glycine. One of the four cultures of healthy tissue on (W) medium containing 4.6 x 10^{-2}M glycine grew at an "explosive" rate of four times the mean growth rate indicated in Table 2

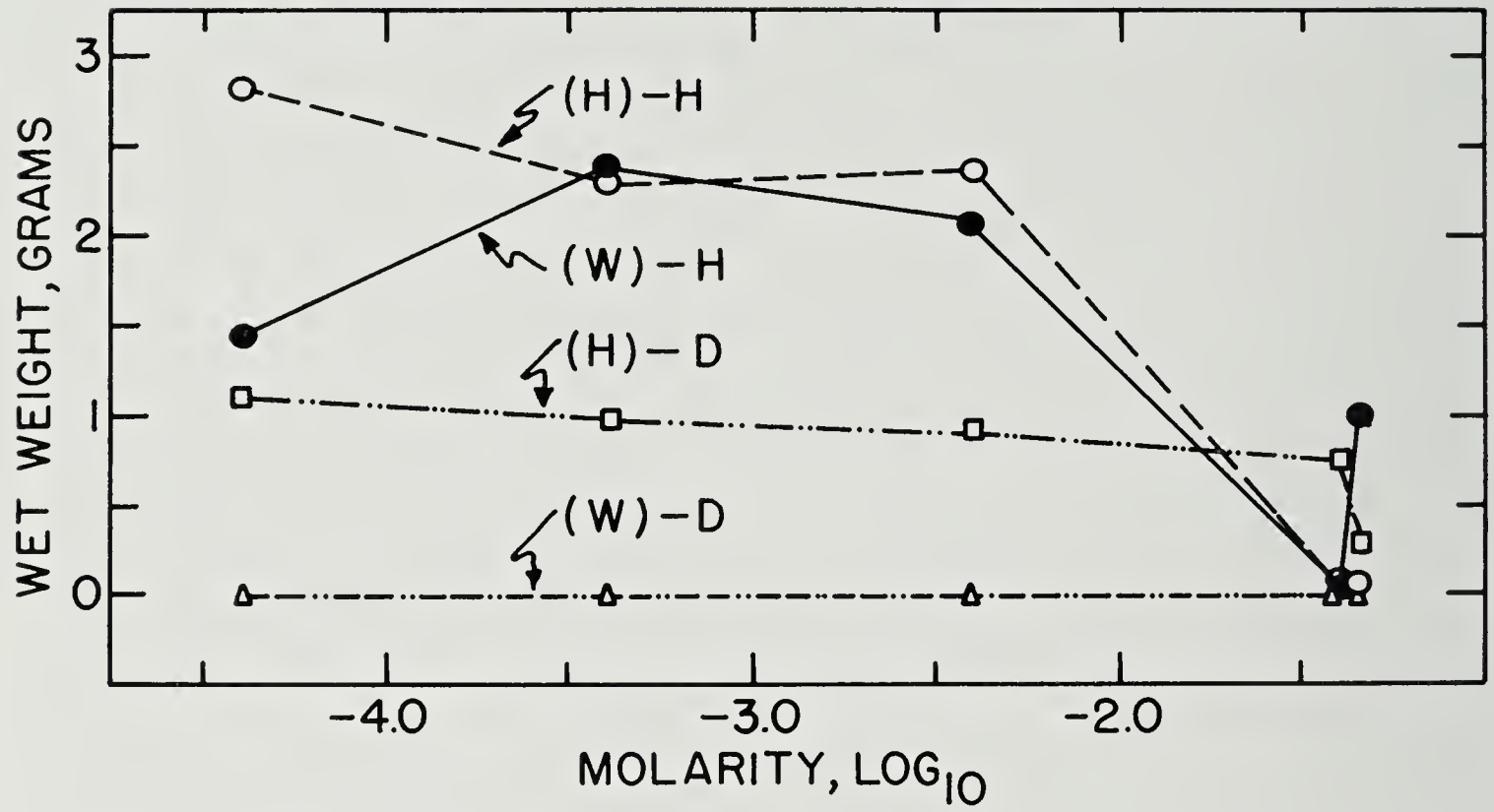

FIG. 1.—Effect of concentration of glycine (abscissa) as measured by wet weight of healthy and Ampelamus-virus-infected cultures of *Nicotiana glutinosa* callus tissue on two media for 35 days at 26° C. Symbols: (H), Hildebrandt medium; (W), White medium; -H, healthy tissue; -D, diseased tissue. (Data from table 2).

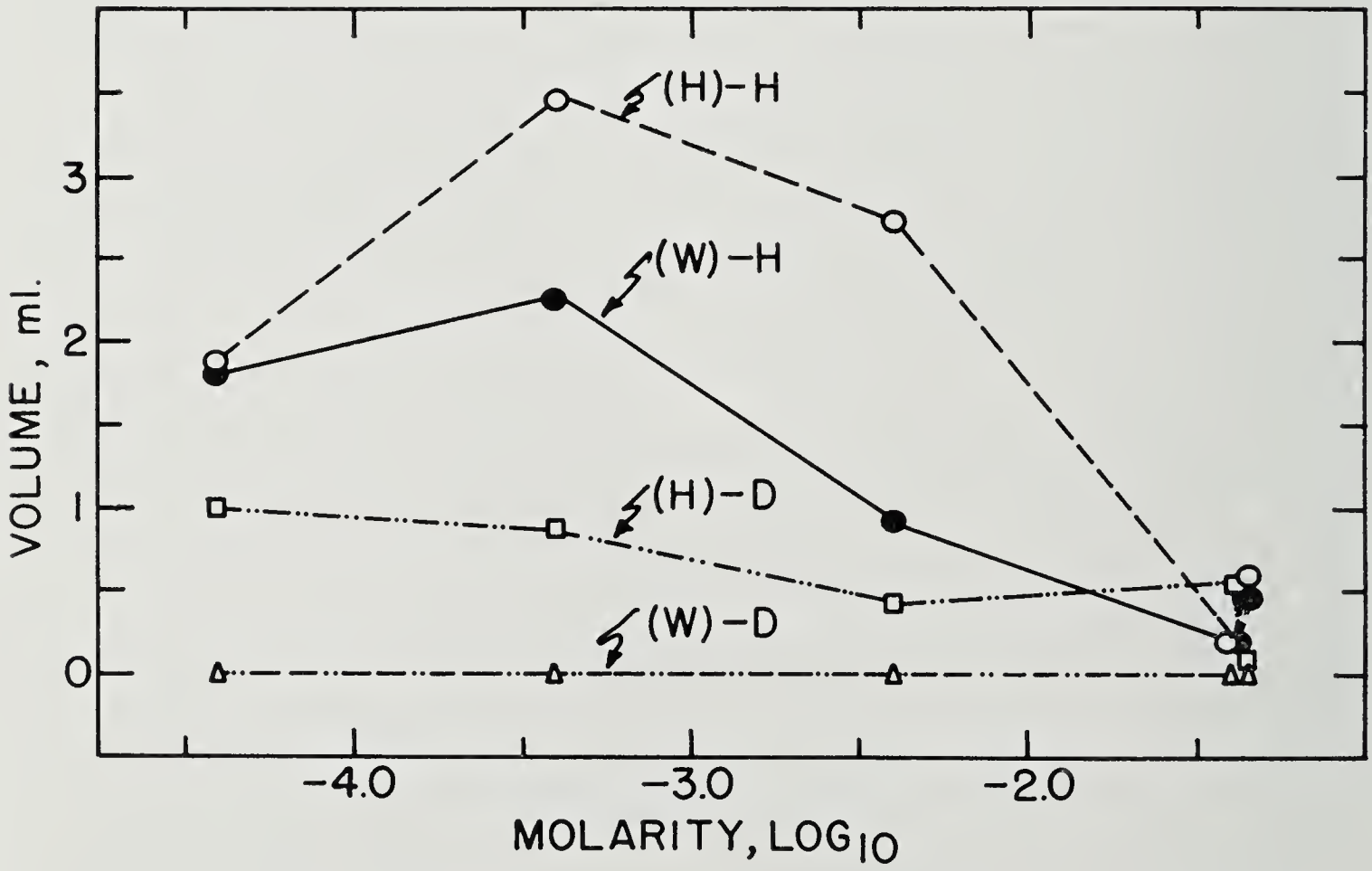

FIG. 2.—Effect of concentration of glycine on the volume in ml of healthy and Ampelamus-virus-infected cultures of *Nicotiana glutinosa* callus tissue on two media for 35 days at 26° C. Symbols: (H), Hildebrandt medium; (W), White medium; -H, healthy tissue; -D, diseased tissue. Coefficient of variability of means: from 6 to 73 for (H)-H, from 14 to 127 for (W)-H, from 18 to 100 for (H)-D.

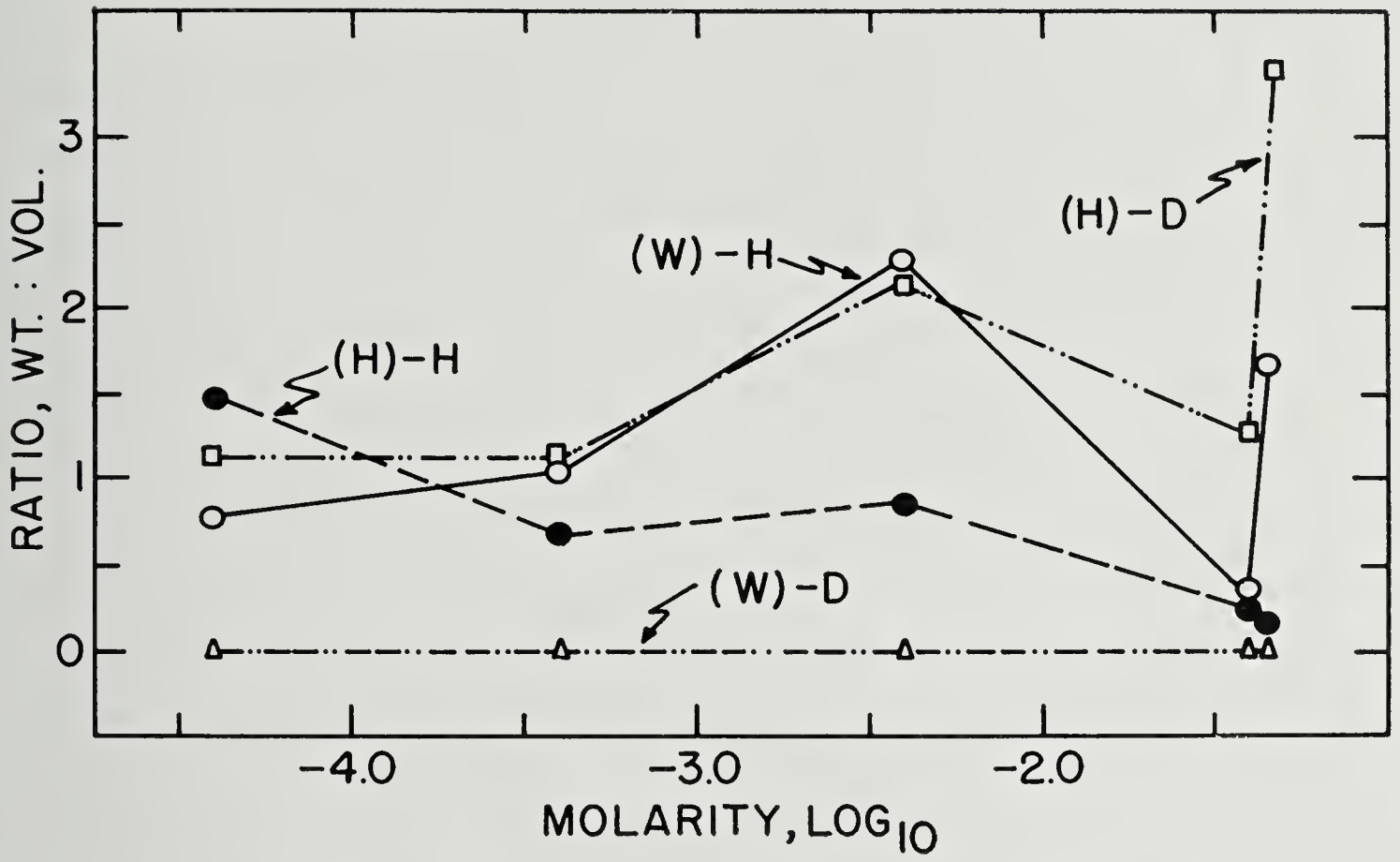

FIG. 3.—Effect of concentration of glycine on ratio of wet weight in grams to the volume in ml of healthy and Ampelamus-virus-infected cultures of *Nicotiana glutinosa* callus tissue on two media for 35 days at 26° C. Symbols: (H), Hildebrandt medium; (W), White medium; -H, healthy tissue; -D, diseased tissue.

and Figure 1. Diseased tissue on the (W) medium made little or no growth at any concentration of glycine tested. Diseased tissue on the (H) medium grew at all concentrations of glycine, but the rate of growth was slower than that of healthy tissue at all concentrations of glycine except 4 and 4.2 x 10^{-2}M.

The results in Figure 2 on growth rate measured by volume are not in close agreement with the results from measurements by wet weight. According to volumetric measurements, 4 x 10^{-4}M glycine is optimal for healthy tissue on either (W) medium or (H) medium. The volume of growth of diseased tissue on (H) medium was not greatly influenced by the concentration of glycine except at 4.6 x 10^{-2} molarity which retarded growth strongly. The diseased tissue on the (W) medium was too small for reliable measurements by volume.

The density of the cultures at varied concentrations of glycine was estimated by calculating the ratio of tissue wet weight in grams to tissue volume in milliliters. These ratios plotted in Figure 3 indicate that the density of healthy tissue on (H) medium correlated inversely with the concentration of glycine. The density of healthy tissue on the (W) medium and also of the diseased tissue on (H) medium was greatest at 4 x 10^{-3}M glycine. Density of growth at 4.6 x 10^{-2}M glycine is not significant since the amount of growth was too small for reliable measurements by either wet weight or by volume.

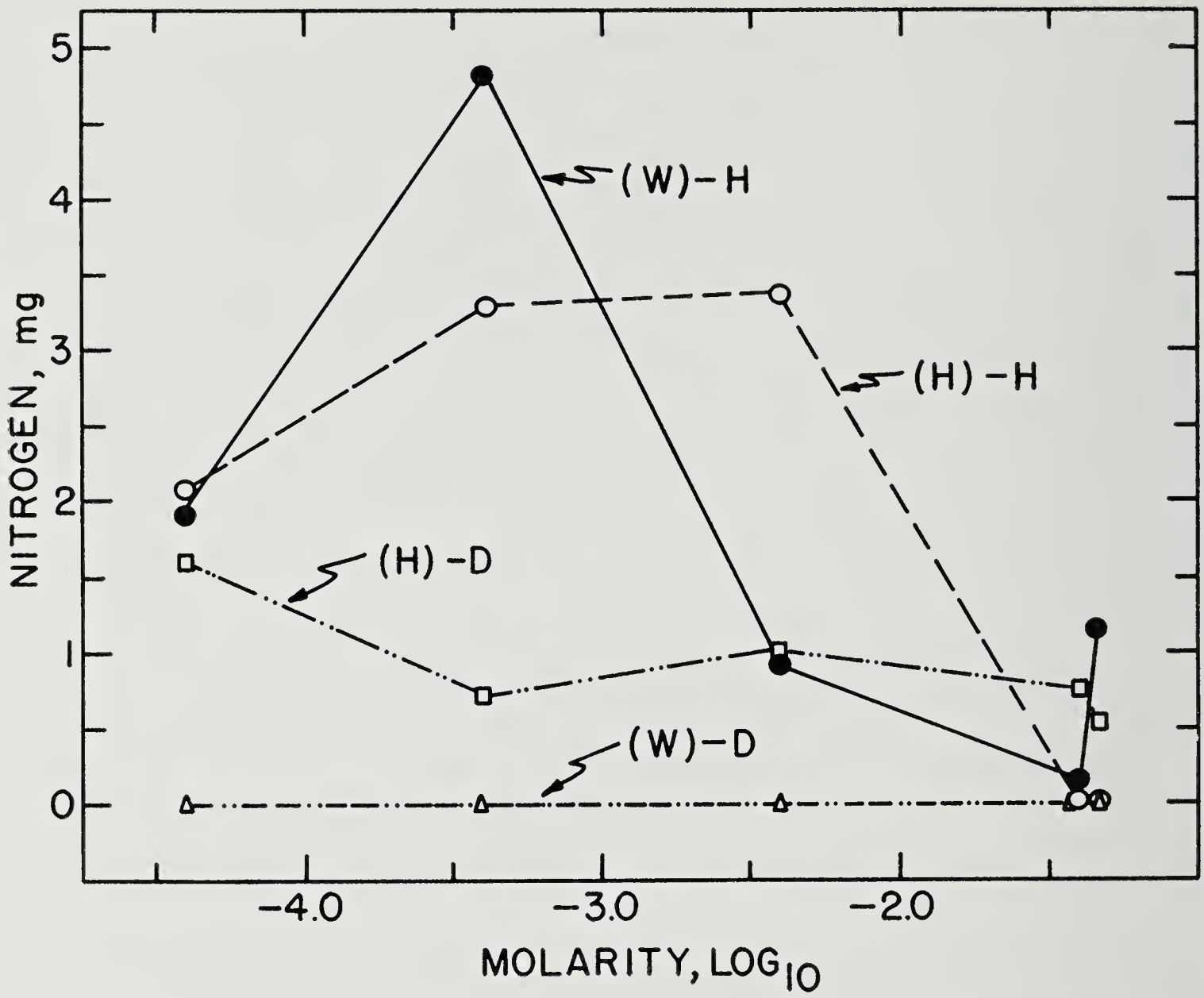

Fig. 4.—Effect of concentration of glycine on total nitrogen of healthy and Ampelamus-virus-infected cultures of *Nicotiana glutinosa* callus tissue on two media for 35 days at 26° C. Symbols: (H), Hildebrandt medium; (W), White medium; -H, healthy tissue; -D, diseased tissue. Coefficient of variability of means: from 2 to 88 for (H)-H, from 16 to 148 for (W)-H, from 18 to 100 for (H)-D.

The magnitude of growth of healthy and diseased tissue on the various media was estimated by determining the amount of total nitrogen in the various cultures. Protein nitrogen was not determined since some cultures were too small even for reliable determination of total nitrogen. Total nitrogen per wet weight of culture as shown in Figure 4 is not in agreement with the results obtained by wet weight measurements. According to nitrogen analyses, maximal growth of healthy tissue occurred at 4 x (10^{-4} and 10^{-3})M glycine in the (H) medium and at 4 x 10^{-4}M glycine in the (W) medium. The growth curve of diseased tissue on (H) medium was somewhat similar to the growth curves determined by volume and wet weight.

Diseased cultures at the completion of the experiments contained infective virus. The amount of virus in the various cultures was not assessed.

Discussion and Conclusions

The data indicate that healthy tissue and Ampelamus-virus-infected

tissue of *N. glutinosa* differ in nutritional requirements.

The similarity of growth rates of healthy tissue on the two media suggests that the nutritional requirements of the healthy tissue was supplied equally well by both media. The (W) medium contained four vitamins, $CuSO_4$ and $AlCl_3$ not included in the (H) medium, therefore it appears that these particular substances had little or no effect on the growth rate of healthy tissue. Even though the concentration of micronutrients common to the two media differed by 0.0034 total molarity, this difference likewise had little or no influence on the growth rate of healthy tissue.

The dissimilarity of growth rates of virus infected tissue on the two media indicate that the nutritional requirements of the diseased tissue differs markedly from that of healthy tissue. Although the growth of diseased tissue on the (H) medium was not as great as that of the healthy tissue on this medium, the nutritional requirements of diseased tissue is partially supplied by the constituents of the (H) medium. The inability of the diseased tissue to grow on (W) medium was not due to lack of essential nutrients because it contained all the nutrients that were present in the (H) medium. The defectiveness of the (W) medium for diseased tissue, therefore, must have been due to (a) one or more of the vitamins, $CuSO_4$, or $AlCl_3$ retarding growth, (b) imbalance of nutrients, or (c) a deficiency in total concentration of nutrients in the medium.

According to the results of these tests, the concentration of glycine in the two media can be increased from 4×10^{-5}M (3 mg/L, the amount in each original medium) to 4×10^{-3}M without retarding the growth rate of healthy tissue. Even a greater concentration of glycine (4×10^{-2}M or 3 g/L) in the (H) medium is tolerated by diseased tissue. Thus, radioactive glycine at a wide range of concentration may be incorporated into the (H) medium for tracer studies on healthy callus tissue or tissue infected with Ampelamus virus.

The data do not suggest a reason for the "explosive" growth of one culture of healthy tissue in the (W) medium containing 4.6×10^{-2}M glycine.

Growth rates of cultures determined by wet weight seem reliable. Volume measurements which seem reasonably reliable have promise since the estimate can be made quickly without destroying the sample for other use. Total nitrogen assessments of growth are unreliable and difficult to obtain especially on small samples of tissues. Density of the tissue cultures appears to be reliable and may be useful in detecting characteristics of cultures that are not ascertainable by wet weight or by volume singly.

Studies are being conducted to ascertain the influence of ionic strength of the (H) medium on the growth of healthy and virus-infected tissues in aseptic culture.

The data support the following conclusions: (a) healthy and Ampelamus-virus-infected tissue of *N. glutinosa* differ in their tolerance and response to concentrations of glycine, (b) the virus-infected and healthy tissue differ in their nu-

tritional requirements, and (c) the failure of the virus-infected tissue to grow on the (W) medium was not due to lack of nutrients. The data suggest that the concentration of glycine in the medium influences the density of growth of healthy and of virus-infected tissue.

Summary

The effect of glycine on the growth rate of healthy and virus-infected tissue was determined for two media: (W) medium, a modification of White's formulation and (H) medium developed by Hildebrandt et al. for healthy tobacco tissue. The (W) medium contained all the constituents of the (H) medium plus four vitamins, $CuSO_4$, and $AlCl_3$. The two media differed by 3.46511×10^{-3} total molarity (70.044×10^{-3}M (H) medium 67.57889×10^{-3}M (W) medium). Concentration of glycine varied from 4×10^{-5}M to 4.6×10^{-2}. Each test included four cultures. Growth rates of healthy tissue on the two media were similar at glycine concentrations from 4×10^{-5}M to 4×10^{-3}M; glycine at 4 and 4.6×10^{-2}M retarded growth. One culture at 4.6×10^{-2}M glycine in the (W) medium grew at an "explosive" rate. Diseased tissue failed to grow on the (W) medium. On the (H) medium, the diseased tissues grew at a moderate rate at glycine concentrations from 4×10^{-5} to 4×10^{-2}, but at 4.6×10^{-2}M glycine, growth was retarded. Measurement of growth rates by wet weight was reliable, reasonably reliable by volume, and unreliable by total nitrogen. Density of cultures calculated as the ratio of wet weight in grams to volume in ml is reasonably reliable.

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THE BOLETOID FUNGUS, *XEROCOMUS PULVERULENTUS*, IN ILLINOIS

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Xerocomus pulverulentus is one of the best documented, most named and least known of the classically described boletes. It is not common, but it is by no means rare, for it has been reported from all parts of Europe and from Ohio, Florida, Idaho and Tennessee in the United States. Specimens collected in Iowa in 1936, 1941 and 1948 were reported on at a meeting of the Iowa Academy of Science in 1950. In the autumn of 1961 Helen Micek, collecting mushrooms near McHenry, Illinois, found a specimen that she had not seen before. She sent it to me, and I found it to be a slightly weathered but completely recognizable sporophore of *Xerocomus pulverulentus*.

Taxonomic Discussion

The first post-Friesian and therefore valid description of *Xerocomus pulverulentus* appears to be that of Opatowski, published in 1836. In 1884 Morgan described a fungus from Ohio to which he gave the name *Boletus mutabilis*. Snell (1934) identified this as *B. pulverulentus*. In 1944 Slipp and Snell published an account of this fungus based upon several collections made in the Kaniksu National Forest in western Idaho. Snell, who did the taxonomic work for this paper, was uncertain as to the most suitable generic name, but in 1951, in describing a reticulate form of *X. pulverulentus* from Tennessee, committed himself to the name *Boletus*. Singer presenting his Florida collections in 1947 also used the generic name *Boletus*.

Eighteen different names have been ascribed to the fungus. This is due in part at least to the many generic changes that have been made in the group. Publication in local journals and confusing descriptions have subjected us to the usual superfluity of specific epithets. Although the original description is rarely seen, it is clear, and accompanied by a colored plate. Kallenbach's illustrations (plate 6, 1926) are excellent and well known. Slipp made colored slides of his collections, and the description that Snell wrote for the paper is fine. Singer also has written a detailed description. There is now no reason for misidentification. Because the pores near the stipe become somewhat irregular and meandering, and because they are adnate; also because the trama seems in our specimens to be not truly bilateral I have chosen to retain Gilbert's name — *Xerocomus pulverulentus* (Opatowski) Gilbert.

Description

This species is distinguished from other species by the fact that the entire sporophore — tubes, pileus, trama and stipe, within and with-

out, turn a vivid and arresting blue when they are touched or broken. The fungus is small, the cap rarely exceeding eight or nine centimeters in diameter. The color is dull and inconspicuous. Our specimens are brown, with a slightly purplish cast (close to 8-C-8 of Maerz and Paul, 1950); the dried specimens are somewhat darker, (about 16-C-6). The tubes are wax yellow, (11-L-4) to old gold, (14-K-5). In drying they darken to approximately the color of the pileus. The stipe is dark brown at the base, sometimes showing a little red. It is lighter above, becoming a pale yellow-brown in the middle, and at the top, yellow like the tubes. Both cap and stem are somewhat pulverulent to the touch, but when rubbed they become smooth. The center of the cap may be depressed. It does not crack; however, it may become diffract or areolate, showing the lighter subsurface. The stem is sulcate and subequal.

The context is considered to be bright yellow, but I have found it almost impossible to see the true color of the flesh. Any attempt to cut, to break, or in any way to handle the fungus produces the blue stain so deep and pervading that the normal color is completely obscured. When the blue fades the color of the context is dull yellow, and the dried specimens have a pale tan flesh. The pores are delicate, small (about 0.50-0.80 mm. in diameter), and irregular. Near the stipe they become larger, coarser and somewhat meandering. The flesh is soft and rather thick, with little or no odor. The taste is mild. Singer says it is edible. Others say it may be poisonous, but I have not found it to be so.

The spores are fusiform, about 12-15 x 4.6 μ in size. The cystidia are often clustered, pale yellow in color and occasionally granular at the tip. They are more numerous at the mouths of the tubes. Singer reports the trama to be bilateral. That is to say, there is a distinguishable denser and slightly colored central portion, while the outer parts are hyaline and relatively loose in organization. This does not seem to be evident in the specimens I have examined.

The habit is gregarious, occasionally caespitose. Single specimens are rarely found. The Iowa specimens were collected in a pasture. I do not know where the specimen found near McHenry was growing. According to Singer, the species is collected near oaks in Florida, usually near *Quercus laurifolia.* Slipp believed that the western forms are typically associated with *Tsuga,* but a sandy or clayey soil that has been disturbed to a depth of a foot or more seems to be more significant. No mycorrhizal associations have been recorded.

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Manuscript received, June 27, 1962.

A MESSAGE FROM YOUR NEW EDITOR

EDWIN C. GALBREATH
Southern Illinois University, Carbondale

Some years ago an ornithologist terminated his tenure as Editor of the *Transactions of the Illinois Academy of Science* by claiming (vol. 52(3-4):171) that his years of service earned for him the right to pass unquestioned through the Pearly Gates into the more desirable part of the Hereafter.

Your new Editor is a vertebrate paleontologist. Consequently, an editorship is the last thing he needs as a means to gain the Hereafter. By the time these words reach the printed page some members of the Academy will testify that a base creature was indeed found and that no amount of editorial activity would certify his passage through the Gates. Your new Editor can not deny that he has summarily and caustically edited some papers. The only word of defense is this: the Academy has a good publication, neat in format and rich in editorial quality. These attributes must be preserved, fostered, and magnified; it is the Editor's fate to promote such aims. Please do your part, submit high quality papers based on top-notch research, and in the format of the Transactions.

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LIVER WEIGHT CHANGES ACCOMPANYING TUMOR TRANSPLANTATION IN RATS AND MICE

LEON L. GERSHBEIN

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When cells of a given transplantable tumor are injected subcutaneously in a recipient animal, the lesion grows at the site of administration. The proliferation of the tumor is not a local or isolated phenomenon but definite systemic changes occur, such as a decrease in the liver enzyme catalase, among others. One or more blood-borne principles originating in the tumor are thus able to affect the liver, an organ which is the major site of metabolism and detoxification. A study of other hepatic alterations in tumorous animals, such as size and solids and water contents would be of great importance in the understanding of tumor growth characteristics and, although such work is reviewed below, the results have often been equivocal.

In an early study, Schlottman and Rubenow (1932) reported that the water content of blood and liver, and to a lesser degree, kidney, from rats with Jensen and Flexner tumors ranged higher than in the corresponding controls; the reverse was noted for brain and muscle. Although no details were given, McEwen and Haven (1941) stated that the transplantation of carcinosarcoma 256 directly into the liver of rats caused an increase in hepatic water content. Similar results were obtained with the tumor transplanted subcutaneously provided that the lesion had reached a certain weight level (10 gm). The elevation in hepatic water content was independent of diet, underwent no further rise with more advanced tumor growth and did not stem from a decrease in dry liver weight. Yeakel and Farris (1947) noted liver enlargement in old female rats with spontaneous tumors as compared to old males or younger females. The study was extended to include a fibrosarcoma and a primary tumor arising from injection of methylcholanthrene (Yeakel, 1948). No unequivocal relationship existed between tumor size and hepatic enlargement, but the findings were more consistent with females. Actually, the augmentation was significant where the lesion weighed over 30 gm and the body length exceeded 175 mm and it was attributed to protein anabolism accompanying tumor proliferation. In the presence of large tumors, the hepatic nitrogen mounted, the accumulation paralleling the total body weight (Yeakel and Tobias, 1950; 1951). Previously, it had been shown that during Walker tumor growth, the nitrogen content of the lesion was higher than that stored by the host (Mider *et al.*, 1948; Sherman *et al.*, 1950).

Liver size and catalase depression have also been studied. Appleman, Skavinski and Stein (1950) reported an increase in liver weight accompanying hepatic catalase diminution in rats with a fibrosarcoma and the Jensen sarcoma. Liver wet-weight and nitrogen were also increased with chorioallantoic implants of Brown-Pierce carcinoma as well as the Jensen tumor in the chick embryo (Skavinski and Stein, 1951). Dounce and Shanewise (1950) pointed out that in view of the well known reversion to normal catalase levels on tumor extirpation, it is difficult to account for the lower enzyme concentration in the tumorous animals on the basis of liver enlargement. Marked increases in liver size have also been demonstrated with a transplantable rat lymphosarcoma, a C_3H mammary carcinoma and several DBA mouse tumors as well as in the presence of egg-grown tumors (Kynette *et al.*, 1945; Klatt and Taylor, 1951; Knox *et al.*, 1952). A perusal of such data reveals that although wet liver enlargement due to tumor could be discerned in several cases, no definite increases are evident in the dry liver weights (Knox *et al.*, 1952). In rats with a transplantable fibroadenoma, a mixed fibroadenoma - fibrosarcoma undergoing malignant alteration and a fibrosarcoma, hepatic enlargement could be observed only on the basis of carcass weight; the depression in catalase was quite sharp when the tumor underwent malignant transformation (Begg *et al.*, 1953). According to Annau, Manginelli and Roth (1951a), rats with a reticuloendothelioma displayed increases in liver:total body weight ratios as the tumor approached an optimal weight; the results were more divergent with mice bearing a fibrosarcoma or various mammary tumors. Recently, an increase in the ratio has been reported for rats injected with Walker and Flexner-Jobling tumor extracts as well as in animals with these lesions amounting to 4% of the total body weight; the findings were negative with Jensen and Novikoff tumors and extracts (Kampschmidt *et al.*, 1960).

The present study was undertaken with the view of following liver weight changes in mice injected with four different tumors and in rats, with Jensen and Walker tumors. The latter was also introduced into the caudal lobe of the liver. Emphasis was directed toward the determination of any possible increase in dry liver weight over the controls. Also, to resolve difficulties relative to calculation of percentage liver weight on the basis of either total body or carcass weights, older or heavy animals were used in some of the series.

Materials and Methods

Animals.—The male rats were of the Sprague-Dawley strain and Swiss and BDF_1 strains were employed in the mouse experiments. The rats were housed individually and the mice up to six per cage. Laboratory Chow and water were administered *ad libitum*.

Tumor Transplantation.—The Jensen and Walker tumor-saline suspensions (1:20) were injected into the rats in amounts of 0.30 ml, the controls receiving the same volume of saline. The Ehrlich ascites tumor was administered intraperitoneally

and as in all cases, extreme care was taken to deliver the identical amount to each animal. For leukemia, Tumor L1210, a total of 100,000 cells was inoculated intraperitoneally per mouse. Generally, these animals succumbed by the ninth day so that the test period comprised seven days. Tumor S-180 fragments of 0.1 ml in volume were injected into the leg by trocar and Tumor 755 (0.2 ml of 'standard' suspension) was administered subcutaneously. In one series, rats were anesthetized (ether), the abdomen incised and 0.025 ml of stock Walker suspension injected into the caudal lobe (Gershbein and Elias, 1954); the respective controls were treated in the same manner except that

TABLE 1.—Wet and Dry Liver-Total Body Weight Ratios for Mice with Transplanted Tumors.[a]

Treatment	No. of mice	Average body weight at necropsy, gm	Wet liver per 100 gm body weight, gm	t	Dry liver per 100 gm body weight, gm	t
Group 1-4 (BDF$_1$ males; duration: 12 days)						
Controls.....	50	19.6 ± 0.39	5.665 ± 0.088	.....	1.673 ± 0.826	.....
Tumor 755...	43	21.3 ± 0.46	5.708 ± 0.233	0.18	1.596 ± 0.044	1.57
Group 3-10 (BDF$_1$ males; duration: 12 days)						
Controls.....	43	19.6 ± 0.37	5.056 ± 0.101	.....	.....	.....
Tumor 755...	36	20.7 ± 0.30	5.119 ± 0.083	0.74	.....	.....
Group 4-18 (BDF$_1$ males; duration: 15 days)						
Controls.....	38	20.5 ± 0.24	5.174 ± 0.071	.....	1.403 ± 0.019	.....
Tumor 755						
Based on total body weight	27	21.7 ± 0.36	5.138 ± 0.078	0.33	1.392 ± 0.023	0.38
Calculated on basis of carcass weights	.....	19.4 ± 0.32	5.756 ± 0.130	4.01[b]	1.550 ± 0.028	4.45[b]
Group 5-21 (Swiss females; duration: 8 days)						
Controls.....	30	21.5 ± 0.41	5.889 ± 0.167	.....	1.741 ± 0.035	.....
Tumor S-180.	28	18.5 ± 0.43	6.372 ± 0.158	2.10[b]	1.728 ± 0.039	0.24
Group 6-33 (BDF$_1$ males; duration: 7 days)						
Controls.....	30	20.1 ± 0.31	4.611 ± 0.064	.....	1.364 ± 0.019	.....
Leukemia....	40	22.6 ± 0.61	5.594 ± 0.150	5.40[b]	1.424 ± 0.030	1.54
Group 7-50 (Swiss males and females; duration: 8 days)						
Controls.....	20	24.0 ± 0.36	5.559 ± 0.121	.....	1.596 ± 0.036	.....
Ehrlich Ascites Tumor	23	20.9 ± 0.67	7.211 ± 0.340	4.33[b]	1.882 ± 0.089	2.73[b]

a The standard error follows each ± sign in all cases.
b $P < 0.05$.

saline only was introduced. Where spillage was apparent at surgery or necropsy, such animals were excluded from consideration.

Liver Removal. — The animals were sacrificed (ether), the body weights recorded and the livers removed, drained in gauze and weighed. They were dried to constant weight in an oven at 100° C and the percentage water content determined.

Results

Average mouse body weights at necropsy, ratios of wet and dry liver to total body weight and the pertinent Fisher t values are listed in Table 1. Animals with Tumors S-180 and 755 were sacrificed after eight and twelve days, respectively, following transplantation and at necropsy the average wet tumor weights were 750 mg and 1100 mg in the order given. In one series employing Tumor 755 where the duration was fifteen days (Group 4C-18), the mean wet tumor weight was 2.29 ± 0.28 gm; the relevant liver percentages are calculated on the basis of both total body and carcass weights. No sex differences were noted in the ratios with the mice sacrificed eight days after transplantation of the Ehrlich ascites tumor, the sexes being about equally represented in both the controls and tumor-bearing animals. Similar liver data for male rats with Jensen and Walker tumors together with average wet tumor weights are shown in Table 2; the intervals following transplantation were eighteen and thirty days. The pertinent ratios obtained with rats in which Jensen tumor did not 'take' are also compared with the corresponding control values. The duration was 10.5 days for the series injected with Walker tumor directly in the liver (Group 11-86A,B). For the latter, tumor was carefully dissected prior to liver processing. In general, macroscopic hepatic findings were not remarkable except with the leukemic mice in which the livers were pale in color.

Discussion

As calculated on the basis of total body weight, mice bearing Tumor 755 and sacrificed after a period of twelve or fifteen days displayed no significant increase in either wet or dry liver weights over the respective controls (Table 1). The dry liver contents were likewise not increased with the Tumor S-180 and leukemia series but the wet liver:total body weight ratios were definitely elevated. However, mice of either sex with the Ehrlich ascites tumor underwent an increase in percentage wet liver and that this was not due to water alone can be noted from the significant elevation in dry liver:total body weight ratio.

In marked contrast to the above findings with Tumor 755 (Group 4-18), when the wet and dry liver ratios were evaluated in terms of carcass weight (body weight excluding the mass of the lesion), both were definitely elevated. It will be recalled that the calculation of liver weight changes on the basis of either carcass or total body weights has posed a distinct problem. Thus, the opinion of McEwen and Haven (1941) is shared by the writer, name-

TABLE 2.—Liver-Total Body Weight Findings for Male Rats with Transplanted Jensen and Walker Tumors.[a]

Treatment	No. of rats	Average body weight at necropsy, gm	Mean tumor weight, gm	Wet liver per 100 gm body weight, gm	t	Dry liver per 100 gm body weight, gm	t
Group 8-40 (Duration: 18 days)							
Controls	25	523 ± 10.3[b]	.....	2.964 ± 0.081	.....	0.889 ± 0.018	.....
Jensen Tumor	24	480 ± 13.1	26.5 ± 11.5	3.939 ± 0.117	7.02[c]	1.074 ± 0.016	6.32[c]
Walker Tumor	31	485 ± 5.5	23.7 ± 5.4	4.298 ± 0.095	10.31[c]	1.052 ± 0.019	6.03[c]
Group 9-32 (Duration: 18 days)							
Controls	18	163 ± 5.9[d]	.....	4.848 ± 0.123	.....	1.311 ± 0.029	.....
Jensen Tumor (Over-all)	21	135 ± 6.9	6.80 ± 1.40	5.733 ± 0.214	3.43[c]	1.413 ± 0.044	1.89
Tumor	11	.....	2.30 ± 0.35	5.348 ± 0.268	1.92	1.372 ± 0.072	0.91
Tumor	10	.....	12.0 ± 1.8	6.149 ± 0.300	4.71[c]	1.450 ± 0.050	2.62[c]
Negatives[e]	8	136 ± 14.5	.....	5.163 ± 0.304	1.16	1.328 ± 0.060	0.29
Group 10-14 (Duration: 30 days)							
Controls	25	471 ± 8.9	.....	3.030 ± 0.085	.....	0.888 ± 0.016	.....
Jensen Tumor	22	513 ± 12.1	63.4 ± 8.1	3.770 ± 0.103	5.60[c]	0.958 ± 0.019	2.80[c]
Negatives[e]	10	456 ± 10.4	.....	3.035 ± 0.106	0.03	0.885 ± 0.022	0.10
Group 11-86A, B (Duration: 10.5 days)							
Controls	18	296 ± 6.0	.....	3.490 ± 0.054	.....	1.013 ± 0.016	.....
Walker Tumor Injected into caudal lobe of liver	19	278 ± 5.3	1.76 ± 0.15	3.667 ± 0.062	2.12[c]	1.009 ± 0.014	0.20

a Except for the last group, tumor was transplanted subcutaneously.
b The controls averaged higher in initial weight, the value being 518 gm as compared to the mean of 470 gm for the tumor animals.
c $P < 0.05$.
d Average initial weight for rats of this group: 94 ± 4.9 gm.
e Rats transplanted with Jensen cells but in which tumor was absent.

ly, that the tumor should be viewed as an integral part of the entire organism rather than a foreign or extraneous entity. Reference has already been made to similar calculations by Begg, Dickinson and Millar (1953). Although Yeakel (1948) could not correlate percentage liver based on carcass weight with tumor size, in her later study with Tobias (1951), the relative amount of hepatic nitrogen was greater in rats with large tumors only when computed in terms of carcass weights. Also, an elevated sensitivity noted with female tumorous animals in earlier work (Yeakel, 1948; Knox *et al.*, 1952), was not too apparent in the present study.

On the basis of total body weights, the wet liver percentages were increased in heavy rats bearing both large Walker and Jensen tumors (Groups 8-40 and 10-14; Table 2). It will also be noted that this stemmed in great measure from an increase in liver solids, the dry liver:body weights likewise being markedly elevated for both groups. In one series (Group 9-32), Jensen tumor implanted subcutaneously and averaging 6.80 ± 1.40 gm in weight caused an over-all increase in wet liver weight to the exclusion of any statistically significant change in the dry liver:body weight ratio. However, when the data from the treated animals were analyzed on the basis of tumor size, half of the rats which possessed lesions averaging 12.0 ± 1.8 gm in weight displayed both increases in wet and dry liver percentages; with the remainder (average tumor weight: 2.30 ± 0.35 gm), the wet liver:total body weight ratio was elevated over the controls but not to a statistically significant degree. As might be expected, no increase in wet liver weights ensued with animals injected with tumor cells but in which the lesion did not take. A rise in percentage wet weight occurred with rats bearing Walker tumor in the liver (average: 1.76 ± 0.15 gm; Group 11-86A,B) but the corresponding dry liver:body weight ratio was not affected. Presumably, a relatively small tumor present in the liver might predispose to a greater effect on the percentage wet liver as compared to the subcutaneously transplanted series discussed above (Group 9-32).

It should be pointed out that in the larger animals, body weight gains are reflected primarily in fat deposition whereas in the young growing rats, tissue nitrogen is still being laid down. Also, in those bearing rapidly growing tumors, an elevation in carcass water has been demonstrated (Rechcigl *et al.*, 1961). In fact, the use of dry rather than wet carcass weights has been recommended by Haven, Mayer and Bloor (1961) in carrying out various comparisons between control and tumorous animals, a practice not explored in the current study.

The present findings further attest to a definite role of the liver in tumor growth and proliferation. Certainly, a variety of factors are involved in the increased liver size and must encompass a rise in the amount of hepatic water and possibly an increased content of solids as well as an elevated anabolism. A partial explanation has been advanced by Annau, Manginelli and Roth (1951b) based on an increased mitotic activity of the liver. In tu-

morous mice displaying especially high liver to body weight ratios, the mitochondria were enlarged and fine granular to the virtual absence of rod or filament shapes. Distinct mitochondrial changes would be expected on the basis of the increased water content of the tissue (Opie, 1947).

Summary

The ratio of wet or dry liver to total body weights in BDF_1 male mice bearing the carcinoma, Tumor 755, did not vary markedly over the respective control values, the duration of the experiments being twelve and fifteen days. For the fifteen day series, increases in both ratios ensued when these were computed on the basis of carcass weights. The wet liver:total body weight ratios were significantly elevated in Swiss mice with Sarcoma 180 and BDF_1 animals injected with leukemia (L1210) but the corresponding dry liver ratios were in the range of the controls. Swiss mice of either sex bearing the Ehrlich ascites tumor displayed marked elevations in both the wet and dry liver percentages over a period of eight days as was also the case of very heavy rats with Jensen and Walker tumors (duration: up to 30 days). Liver enlargement did not occur in rats in which the tumor did not 'take' or in a series where the Jensen tumors were small (average weight: 2.3 gm). The hepatic water content was significantly higher in rats in which Walker tumor was transplanted directly into the liver (average weight: 1.8 gm) to the exclusion of any increase in liver solids or dry liver: total body weight ratio.

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EXPERIMENTAL REPLACEMENT OF OOLITIC LIMESTONE BY FLUORITE

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In 1944, Dr. R. M. Grogan, then on the Illinois State Geological Survey staff, started an experiment designed to determine if fluorite could be formed by replacement of oolitic limestone in a non-acid environment at room temperatures. Four single-neck Erlenmeyer flasks containing limestone chips immersed in N/2 solution of sodium fluoride were prepared, sealed, and marked to be opened after a period of 3 to 6 months. For several reasons the experiment was forgotten but recently two flasks were opened and the limestone chips, now partially replaced by fluorite, examined.

The conversion of calcite to fluorite by the reaction of hydrofluoric acid solutions (Grayson, 1956) and the basic reaction of alkaline sodium fluoride solutions (Ames, 1961; Pasquali and Bisque, 1962) has been previously demonstrated. Grogan's experiments are of interest because of their long duration and because they afford an opportunity to observe the experimental replacement of the variety of limestone actually replaced by fluorite in bedding-replacement deposits in the Cave-in-Rock district, Hardin County, Illinois where important ore bodies occur in oolitic portions of the Ste. Genevieve Limestone. Favorable ore horizons occur at the top of the Ste. Genevieve and at the top of the lowermost member of the Ste. Genevieve and are overlain by relatively less permeable shale, sandstone, or sandy limestone stata. The ore-bodies are localized along minor fracture systems and it is postulated (Weller *et al.*, 1952, p. 127) that ore-forming solutions ascended along major faults in the area and spread outward and upward along intersecting minor fractures. It was assumed that the solutions were basic or near neutral in their reaction with limestone although previous writers referred or alluded to reactions involving hydrofluoric acid (Weller *et al.*, 1920; p. 275-281, Currier, 1944, p. 36-39).

The Experiment

The experiment set up by Grogan was as follows: Four flasks were prepared, each containing oolitic limestone of the Ste. Genevieve Formation immersed in 200 cc. of N/2 sodium fluoride solution made with distilled water. Twenty grams of limestone chips, crushed to pass a 4-mesh sieve and be retained on an 8-mesh sieve, were immersed in each of two flasks. The average diameter of the chips was about 3 mm. Two pieces of limestone were similarly immersed in each of the two other flasks. These pieces ranged from 6 to 18 grams in weight and the piece subsequently studied had a maximum diameter of 27 mm. The 4

flasks were closed with rubber stoppers and sealed, air tight, with paraffin.

Present Study

Two flasks were opened, one containing the coarse oolite pieces and the other containing smaller chips. The limestone was recovered and washed in distilled water. One of the coarse pieces was saved for analysis. The other, mounted in plastic, was used in the preparation of polished and etched surfaces. The smaller chips were embedded in plastic and thin-sections were prepared from them.

The liquid in both flasks contained a number of plate-like aggregates of tiny crystals that were recovered by filtration and subsequently studied by x-ray diffraction. The filtrate was evaporated to dryness and the crystallization products x-rayed to determine the mineral composition.

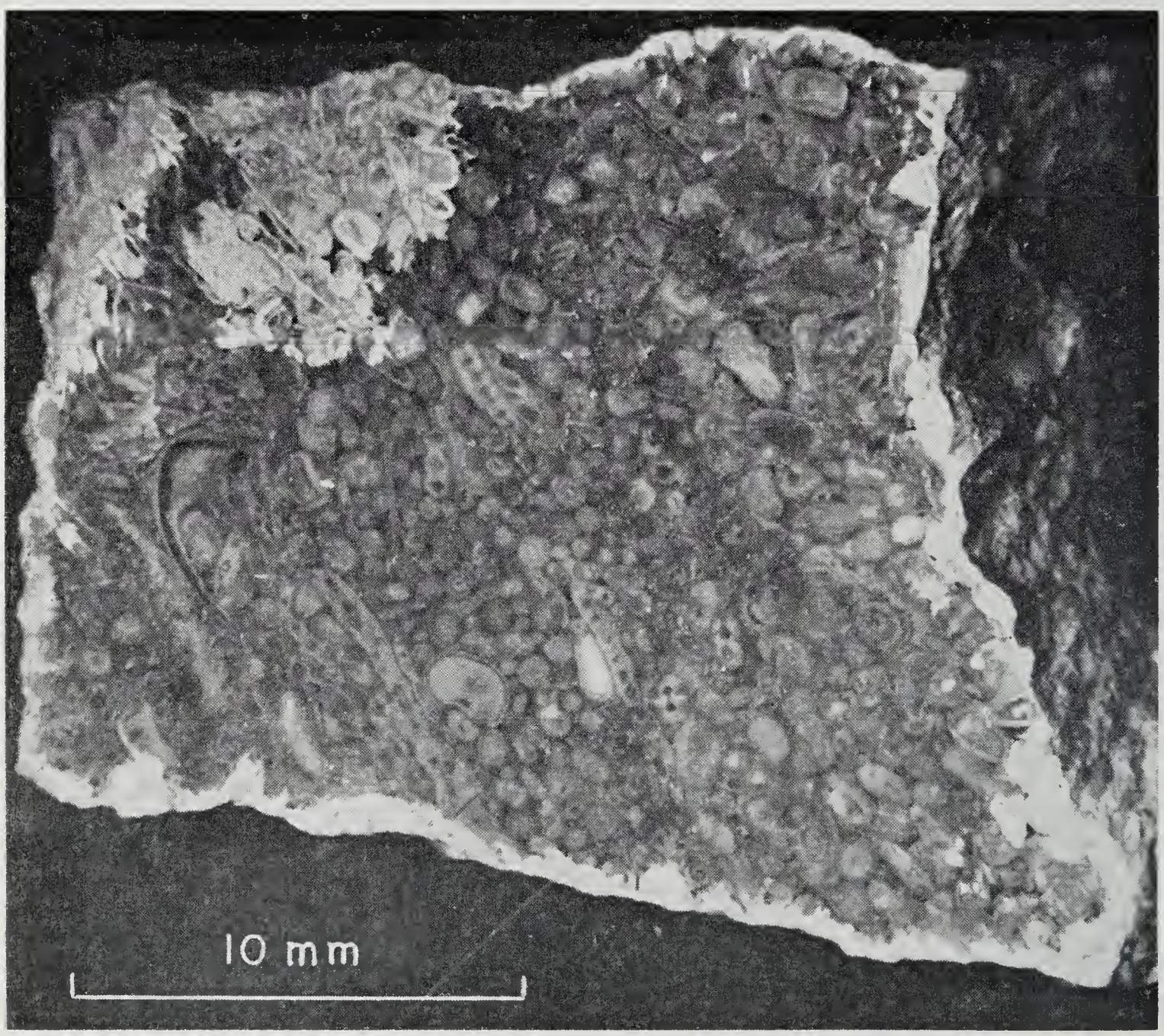
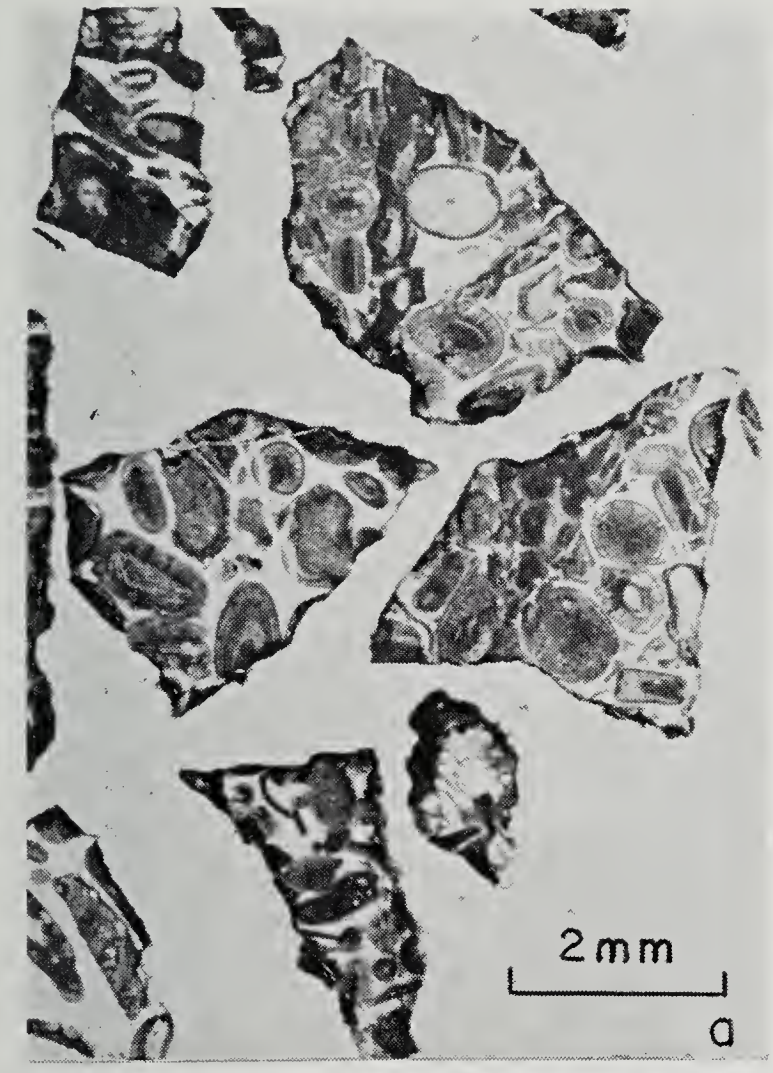
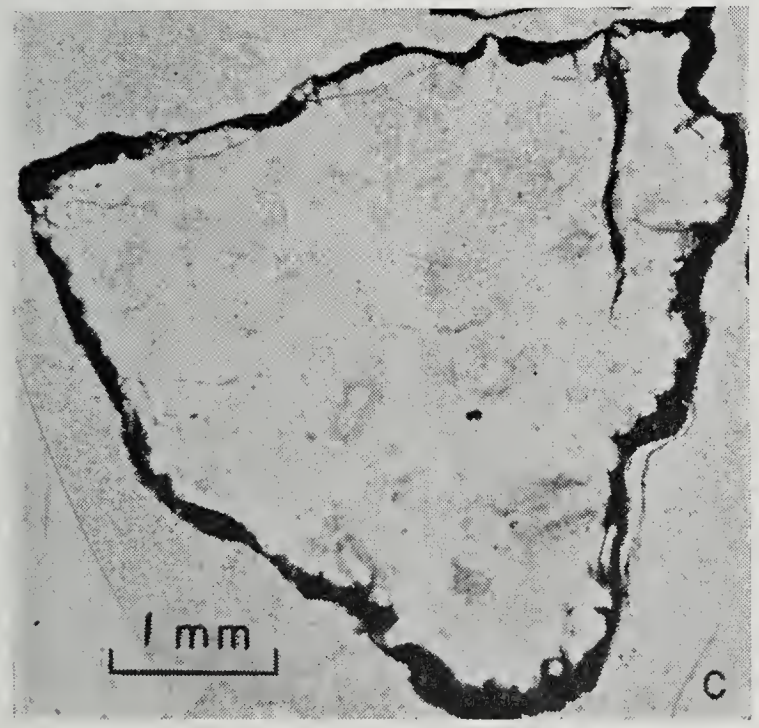


Figure 1.—Polished section of a large piece of oolite having a marginal replacement layer of fluorite. The preservation of the oolitic texture of the original rock is well shown in the upper left of the picture as is a sharp line between the oolite grains and the calcite matrix indicating selective replacement of the grains. Reflected light.





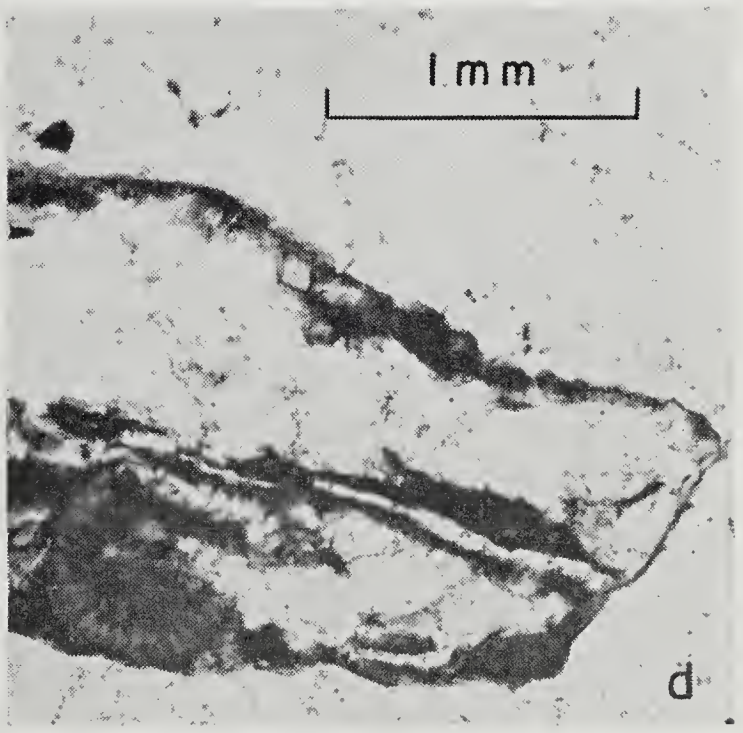


FIGURE 2.—Replacement layers of fluorite on small chips of oolitic limestone. (a) Thin section of small oolite chips having thin marginal deposits of fluorite that appear black. Transmitted light. (b) Much enlarged photograph of a thin section showing a replacement fluorite layer (black) coating an oolite rock fragment. Transmitted light. (c) Thin section that has been acid-treated to remove carbonates showing a surficial replacement layer of fluorite and replacement along a minute crack. Transmitted light. (d) Thin section that has been acid-treated to remove carbonates showing an oolite grain partly replaced by fluorite (dark gray). Transmitted light.

Results

The limestone chips were replaced at their outer surfaces by a layer of microcrystalline, white fluorite that retained the original oolitic texture. The oolite grains and fossils were selectively replaced in preference to sparry calcite matrix (fig. 1). The thickness of the replacement layer is somewhat irregular being greatest where oolite grains and fossil debris occur at the outer surface of the limestone chip. The average thickness of the replacement layer formed on the coarse oolite chip studied was .29 mm. The extensive area of replacement in the upper left on Figure 1 is due to a surface irregularity rather than deep penetration into the center of the specimen.

The smaller chips were likewise replaced at their outer surfaces (fig. 2). Replacement advanced into the interior of some chips along minute cracks. The average thickness of the replacement layers was 0.11 mm; however, oolite grains occurring near the outer surface in some cases were almost completely converted to fluorite.

The aggregates filtered from the solution consisted principally of fluorite (CaF_2) and calcite ($CaCo_3$), with minor amounts of quartz (SiO_2) and dolomite ($CaMg(CO_3)_2$) as determined by x-ray diffraction.

Determinations of the pH of the solutions yielded values of 9.8 and 10.0, the higher value being for the solution from the experiment involving the smaller oolite chips. These values are in marked contrast to the approximate neutrality of the original solution and reflect the addition of CO_3^{--}ions. By evaporation, 4.8 grams of solid were recovered from the solution having pH of 9.8 and 4.1 grams from that having a pH of 10, but some solid was lost by an accidental boiling action at one point during the evaporation process. Villiaumite (NaF), sodium carbonate (Na_2CO_3), and thermonatrite ($Na_2CO_3.H_2O$) were identified by x-ray diffraction. A fourth phase, tentatively identified as trona ($3Na_2O.4CO_3.5H_2O$) and characterized by 10 Å basal spacing, was also present. Other hydrated forms of sodium carbonate are possibly present in lesser quantities.

Discussion of Results

The design of the experiment does not allow much conjecture as to the mechanism of the calcite-fluorite replacement reaction. Reaction occurred along a replacement front that advanced from the outer surface toward the center of the chips. The replacement is one that involves minerals that contain a common cation and the reaction can be simply stated:

$$CaCO_3 + 2\ F^- \leftrightharpoons CaF_2 + CO_3^{--}$$

This involves removal of the fluoride ion from solution and addition of the carbonate ion to the solution. Ames (1961, p. 738) states that Ca^{++} does not move from its lattice position, only the anions of the replaced solid move into solution. Pasquali and Bisque (1962) report that the common ion does move from its position and reaches equilibrium with Ca^{++} ions in the reaction solution.

The supply of fluoride ions in solution was not exhausted, but it

is assumed that the replacement reaction had essentially, if not completely, stopped. The presence of calcite as a stable component of mineral aggregates in the ambient fluoride-bearing solution suggests that the reaction stopped for some reason other than any inability of fluoride ions to diffuse through the replacement layer of fluorite. It is thought that, as the CO_3^{--} concentration increased during fluorite replacements, the solution became increasingly basic according to the following hydrolytic reaction:

$$CO_3^{--} + H_2O \leftrightarrows HCO_3^- + OH^-$$

which, in turn, depressed the solubility of $CaCO_3$ relative to the solubility of CaF_2 and shifted the equilibrium

$$2F^- + CaCO_3 \leftrightarrows CaF_2 + CO_3^{--}$$

to the left.

The plate-like aggregates filtered out of the solution had the appearance of a precipitate. However, the mineralogical analysis—fluorite and calcite with minor quartz and dolomite — suggests partial replacement of slightly impure high calcium limestone. The presence of dolomite, not known to precipitate from aqueous solutions at room temperatures, seems to rule against precipitation. It is possible that this material flaked off or was abraded from the replacement layer.

The thickness of the replacement layer on the smaller chips is approximately one-third of that on the larger piece of limestone. Ames (1961) shows that the rate of fluoride removal from solution during replacement is directly proportional to calcite surface area. Therefore, because of the greater surface area the initial rate of replacement of the smaller chips was higher and equilibrium was reached after the formation of a thinner layer over the greater area. The total amount of fluorite formed on small chips was probably about equal to that formed on the larger pieces.

Summary

The experimental replacement of oolitic limestone by fluorite is such that the original texture of the limestone is faithfully duplicated by microcrystalline fluorite. The reaction proceeds at room temperatures. The replacement is somewhat selective in that oolite grains and fossil debris are replaced at a faster rate than sparry calcite cement. The amount of surface area exposed to the replacing solution and the pH of the solution were major factors in determining the rate of replacement and the thickness of the replacement layer. It is thought that increased CO_3^{--} concentration and basic conditions, produced by hydrolysis, depressed calcite solubility so that calcite-fluorite-solution stability was attained.

Acknowledgments

The writer is indebted to Josephus Thomas, Jr., who provided the x-ray data involved in this study and to a number of his colleagues for their comments and suggestions.

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CONTACT TEMPERATURE OF A PERIDOTITE DIKE WITH PENNSYLVANIAN SHALE DETERMINED BY CLAY MINERAL ALTERATIONS

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Basic igneous rocks have been encountered in coal mines and in drill holes from time to time in southern Illinois (Clegg and Bradbury, 1956). One such occurrence uncovered in a coal stripping operation near Absher, Illinois, (Clegg, 1955) is of two mica peridotite dikes and their associated stringers. The dikes vary from 8″ to about 10′ in thickness and cut through sedimentary rocks of Pennsylvanian age extending upward into the shale that directly overlies the Harrisburg (No. 5) Coal. Natural coke was formed at the dike contact during intrusion and contact metamorphism of the coal extends only 18″-20″ from the dike.

Clegg (1955) described the dike rock as a mica-peridotite having a seriate-porphyritic texture. The rock is specular in overall appearance, and the only minerals macroscopically recognizable are olivine, pyroxene, biotite, pyrite, and calcite. The phenocrysts are more-or-less equant and consist of stubby, doubly terminated euhedra of olivine and pyroxene as much as 1 to 2 mm in diameter. Along the dike contact a few biotite crystals are 10 to 15 mm across, and olivine and pyroxene may reach lengths of 10 mm. The phenocrysts are enclosed in a blue-gray matrix in which grain size is too small to permit identification of individual minerals.

In thin section the microcrystalline matrix appears to consist mainly of finely shredded biotite, various quantities of chlorite, and some epidote. Serpentinization of olivine and pyroxene has proceeded to the extent that differentiation is often impossible except by crystal form. Accessory minerals include apatite, garnet, magnetite, ilmenite, chromite, and perovskite (?). Secondary minerals are serpentine, chlorite, magnetite, pyrite, calcite, epidote, and leucoxene.

Clegg studied the natural coke by petrographic microscope techniques and by differential thermal analyses (DTA) and concluded that the coal at the contact had been heated to not more than 600° C and that the temperature may have been lower. Sosman (1938) considered the coke inclusions in a similar mica peridotite dike cutting a Pennsylvanian coal bed in western Pennsylvania to have been heated at least to 480° C but not above 550° C. He studied the kinds and amounts of volatiles in the coke and unaltered coal to arrive at his estimate and suggested that the coking temperature had been close to 520° C ± 30° C.

In the present study an estimate of the temperature of the contact

FIGURE 1.—Location of Absher Dike area in southern Illinois, SE ¼ Sec. 34, T. 9 S., R. 4 E., Williamson County.

zone between one of the dikes at Absher, Illinois, and the shale and underclay associated with the No. 5 Coal is based on the clay mineral differences between the unaltered country rock and the contact zone. Laboratory heating of the unaltered clay minerals was used to aid in estimating the contact temperature.

STRATIGRAPHY

The area of study is located in SE¼ sec. 34, T. 9 S., R. 4 E., Williamson County, Illinois (Fig. 1). Here the Harrisburg (No. 5) Coal has been strip-mined and the pit abandoned several years ago. The Pennsylvanian rocks exposed in the pit floor and in the high walls belong to the Carbondale Formation of the Kewanee Group (Kosanke *et al.*, 1960). The rocks throughout this area for the most part have a slight dip to the north toward the deeper portion of the present Illinois Basin.

SAMPLING AND SAMPLE TREATMENT

Figure 2 is a generalized diagram of the field relationships of the various sedimentary rock types and the peridotite dike selected for study. Four samples of the top 1 foot of the underclay were taken at varying distances from the dike; (sample D-1) 30 feet from the dike, (sample D-2) at 20 feet, (sample D-3) at 10 feet, and (sample D-4) 6 inches to 1 foot from the contact. (The actual contact of the underclay and the dike was not observed because of slumping of the spoil bank at that point. The position of D-4 was in-

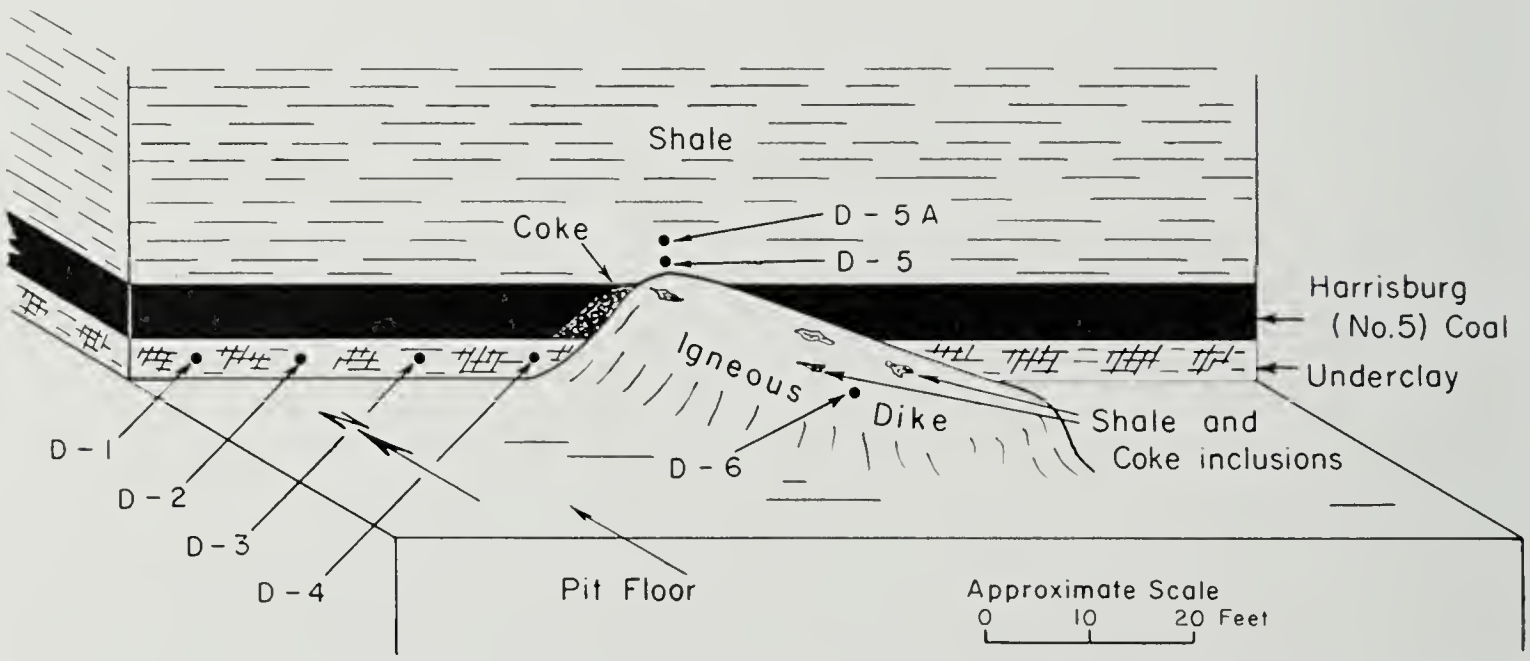

FIGURE 2.—Generalized field relationships of the Absher Dike, Pennsylvanian rocks exposed in the abandoned stripmines, and sample locations.

ferred from the line of intersection of dike with the bed of underclay.) Three samples of the shale above the coal were taken from directly over the dike. (Sample D-5A) at 1½ feet, (sample D-5) at 3 inches, and (sample D-6) was taken from shale pieces partly enclosed in the top of the dike. No chill zone was noted at the contacts with the country rock or on sample D-6. The shale samples were taken from a position where the top of the dike had penetrated only a foot or less into the shale. The dike at this point is approximately 5 feet wide.

Oriented aggregates were made of the $< 2\ \mu$ fraction of each sample and were identified by x-ray diffraction techniques. Some of the samples were placed in an ethylene glycol atmosphere for at least 12 hours to facilitate the identification of any expansible clay mineral present. Sample D-5A was later heated for various times at different temperatures in a small electric furnace in an effort to reproduce a clay mineral suite as much like the D-6 suite as possible.

Figure 3 shows the x-ray traces of the underclay samples D-1, D-2, D-3, and D-4. Each sample contains illite, chlorite, mixed-layer clay material and a trace of kaolinite. Samples D-1, D-2, D-3 are all essentially the same in clay mineral composition and in the quantities of the clay minerals present. Only sample D-4 shows some slight differences from the other three underclay samples. This sample is slightly harder than normal underclay, yet very similar in color and appearance to the other three. D-4 disaggregated and dispersed fairly easily in water during slide preparation, suggesting only slight thermal alteration at best.

The first order illite peak at 8.8° 2θ of the unglycolated D-4 trace is more pronounced than in the other three underclay samples and appears

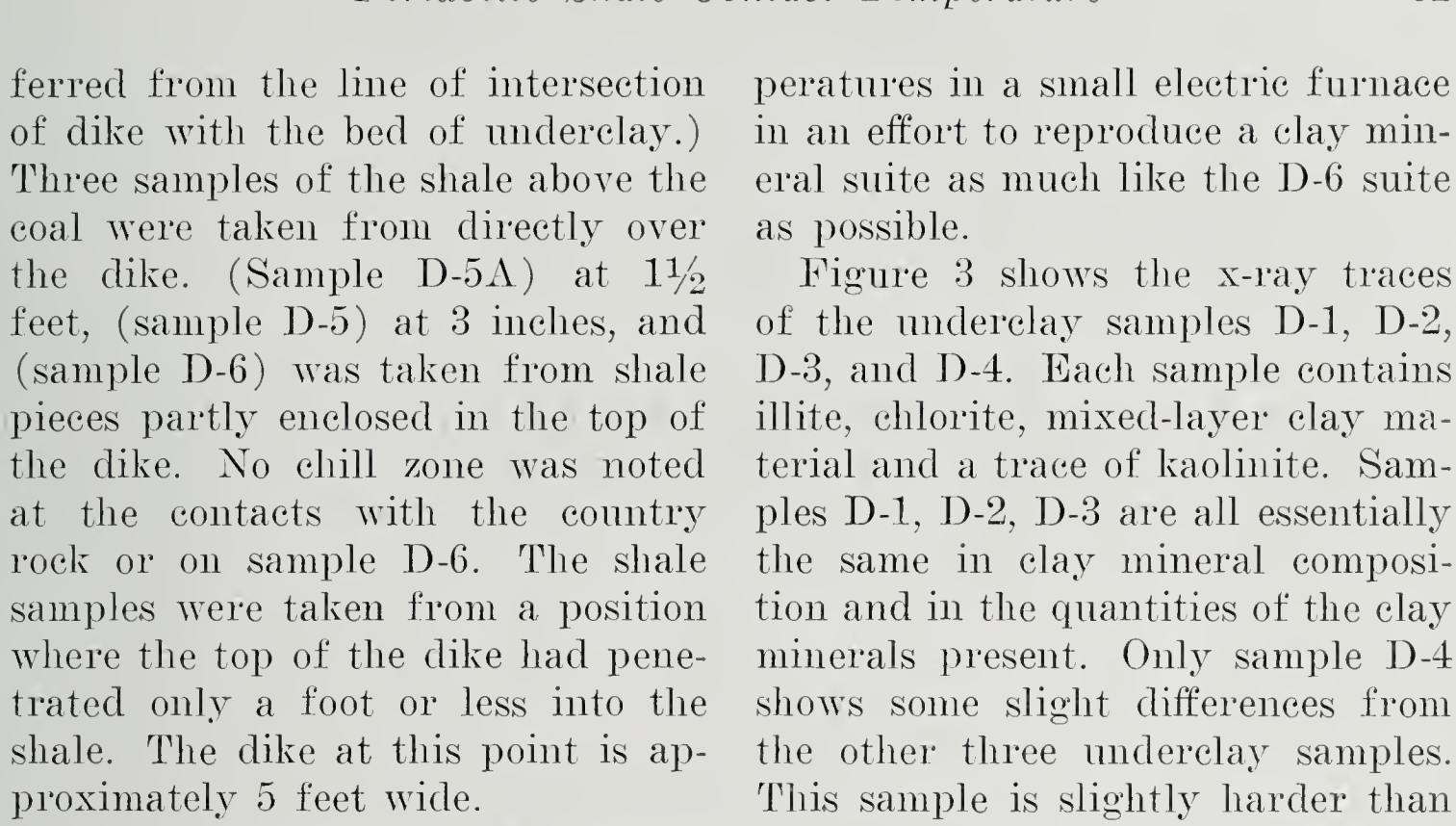

FIGURE 3.—X-ray traces of the <2 micron fraction of top one foot of underclay of Harrisburg (No. 5) Coal.

as if some of the mixed-layer material has collapsed to a 10 Å spacing as a result of the heat of the intruding dike. The x-ray trace of the glycol treated sample D-4 shows a definite increase in the intensity of the first order illite peak when compared to the same illite peak of D-1, D-2, and D-3. The thermal effect of the dike on the clay minerals of the underclay at a distance of about 6″ to 1′ from the contact is very slight.

Figure 4 shows the effect of the temperature of the intruding dike on the clay minerals of the overlying shale. The 002 basal plane reflection of kaolinite and the 004 basal plane reflection of chlorite of the shale samples have been plotted in Figure 5 from x-ray diffraction intensity measurements taken at regular intervals over the 25° 2θ region for samples D-5, D-5A, and D-6 in order to more clearly resolve these reflections. Sample D-5A, 1½ feet above the top of the dike, shows no alteration effects of the dike. The clay minerals of this sample are illite, kaolinite, chlorite, and mixed-layer clay material. Sample D-5, taken 3 inches above the dike-shale contact, shows some differences in the clay minerals when compared with D-5A. The first order illite and chlorite peaks of D-5 are seen to be sharper on both the untreated and glycol treated sample. The sharpening of the illite peak is due to the collapse of the mixed-layer clay material and the sharpening of the chlorite is due to the shift of the same mixed-layer material away from the 5° 2θ area of the curve. Weiss and Rowland (1956) have demonstrated the following relationships: the 001 of chlorite should increase in intensity when heated to approximately 560° C while at the same temperature the other basal reflections of chlorite decrease in intensity; well crystallized kaolinite no longer gives diffraction maxima after being heated to approximately 525° C; the 002 of kaolinite begins to decrease in intensity at approximately 475° C. These temperatures will be lower for kaolinite of poorer crystallinity. The crystallinity of the kaolinite in this Pennsylvanian shale, as well as that of many other Pennsylvanian clays and shales in Illinois, is somewhat poorer than that referred to by Weiss and Rowland (1956). If the sharpening of

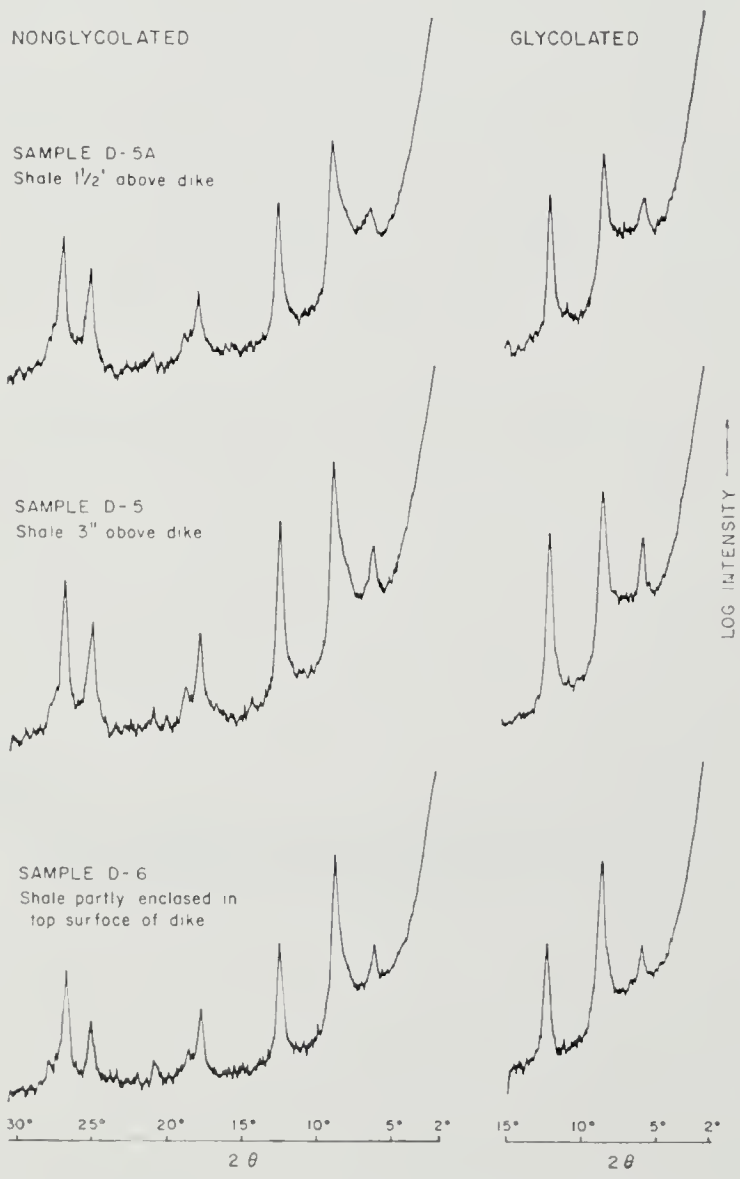

FIGURE 4.—X-ray traces of the <2 micron fraction of the shale overlying Harrisburg (No. 5) Coal.

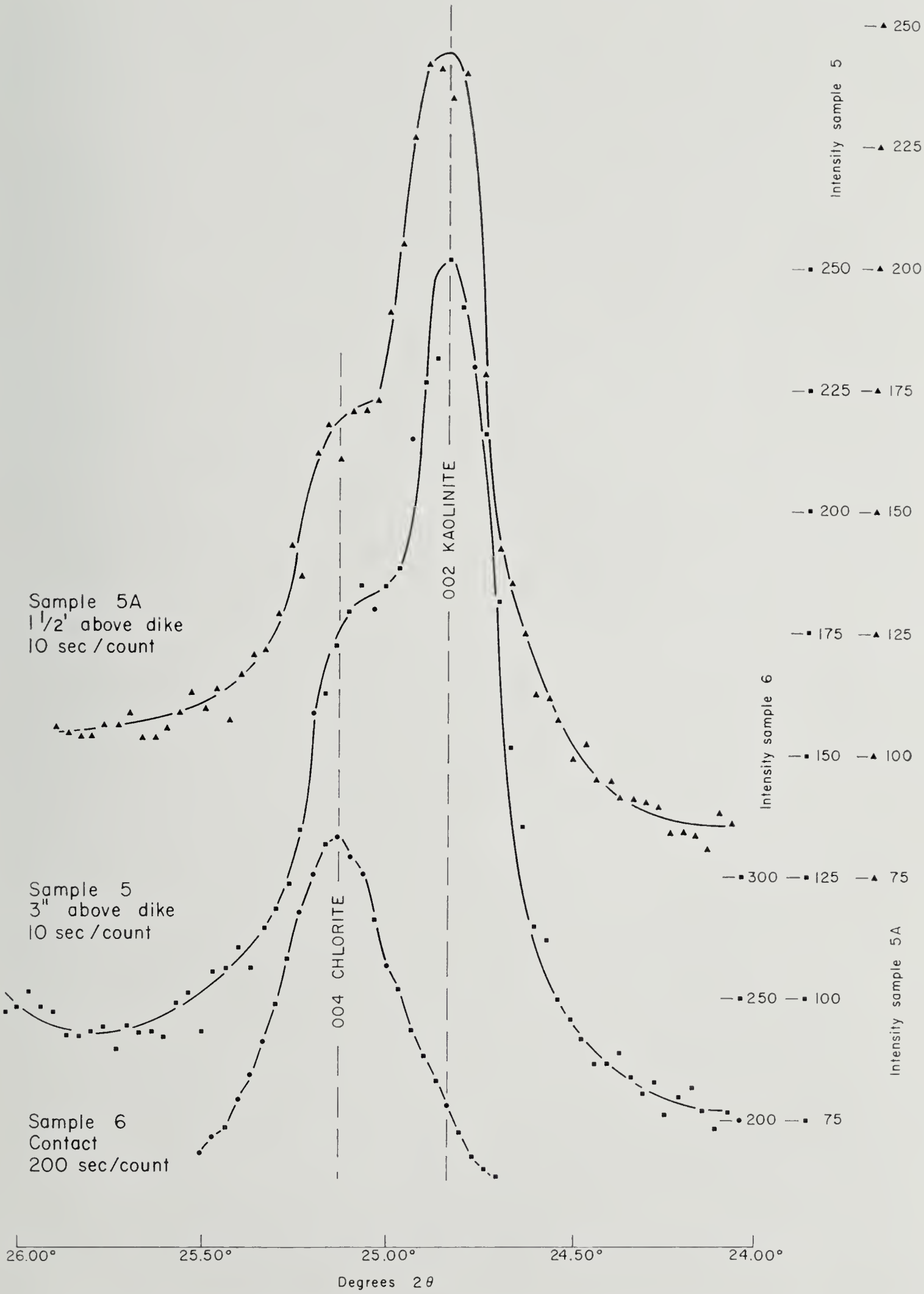

FIGURE 5.—X-ray intensity measurements of the <2 micron fraction of 002 kaolinite and 004 chlorite of shale above Harrisburg (No. 5) Coal.

the 001 chlorite peak of sample D-5 had been caused by temperature, the 002 reflection of kaolinite would have decreased in intensity. Figure 4 shows that this is not the case. Therefore, the maximum temperature to which sample D-5 was subjected is estimated at approximately 400° C.

The clay fraction of D-6 is composed of only illite and chlorite, kaolinite being no longer present (Fig. 5). The 001 of chlorite has not increased in intensity and its other basal reflections do not show a decrease.

A contact temperature of about 525° C to 550° C would seem to be compatible with the findings of Weiss and Rowland if the kaolinite and chlorite in the shale react in the same way as did theirs at elevated temperatures.

Portions of the unaltered shale sample D-5A were heated at various temperatures and times as follows: 400° C for 30 and 140 minutes, 430° C for 30 and 60 minutes, 450° C for 30 and 110 minutes, and 480° C for 15, 45, and 60 minutes. The intensities for the basal reflections of chlorite and kaolinite after each heating are listed in Table 1. The heatings at 400° C and 430° C produced no changes in the intensities of the basal reflections of the $< 2\ \mu$ oriented aggregates of kaolinite or chlorite for the times indicated. Heating at 450° for 30 minutes caused a slight reduction in the intensity of the kaolinite 001 and 002 reflections and after 110 minutes at this temperature the basal kaolinite reflections were subdued even further but were still easily recognizable. After 15 minutes of heating at 480° C, the x-ray diffraction trace was very similar to that produced by 110 minute heating at 450° C. Continued heating at 480° C for 45 minutes further decreased the 001 of kaolinite and left the 002 scarcely perceptible. After 60 minutes heating at 480° C, there is no longer evidence of the 002 reflection of

TABLE 1.—X-ray Intensities of Basal Reflections of Chlorite and Kaolinite After Heating at Various Temperatures for Different Times.

		Chlorite				Kaolinite
C°	Times in minutes	001	002 C + 001 K	003	004	002
400	30	35	90	15	25	40
400	140	35	80	10	25	40
430	30	30	100	15	30	45
430	60	35	95	10	30	40
450	30	35	75	10	25	35
450	110	35	40	10	15	20
480	15	35	45	10	20	25
480	45	35	35	15	20	15
480	60	45	20	15	20	0

kaolinite and the small, poorly defined peak at 12.4° 2θ that remains is attributed to the 002 of chlorite.

The basal reflections for chlorite are not as well developed in the artificially heat treated sample as from those naturally heated. This difference might be expected since there are a number of factors that may have influenced the natural reactions that are not acting in the laboratory heat treatment of the same material.

First, the laboratory heating was in an oxidizing atmosphere, whereas the natural heating probably was under neutral or reducing conditions as is evidenced by the dark gray color of the shale inclusions in the dike and the salmon color or the laboratory heated samples.

Secondly, in the natural heating water probably was present in the system but in the laboratory the heatings were dry.

Third, perhaps at the time of intrusion the chlorite in the shale at the dike contact was able to accept magnesium from the igneous material into its structure at the expense of iron. The resulting more magnesium-rich chlorite would give more intense basal reflections. Analysis of the magnesium content of the chlorite in sample D-6, using the technique of Schoen (1963), showed there to be between 8 and 9 magnesium atoms per 12 octahedral positions.

Fourth, all of the temperature estimates in this study have been made on the assumption that the effect of pressure near the contact of the dike and the shale resulting from their possible deep burial at the time of intrusion was of little consequence. Clegg (1955) states . . . "Field evidence indicates that pressure was not excessive at the time of igneous activity. The conspicuous jointing above the coal and the dike in the southeast highwall points to a release of pressure as a result of tension-fracturing prior to the advance of the rising igneous material. The manner in which the small dike stringers are controlled by fractures in the country rock also indicates that fracturing had opened avenues in advance. It is difficult to understand how a stringer of material less than one-half inch thick could advance for several feet into country rock unless crevices were already present. An apophyseal dike nearby consists of amygdaloidal rock, showing that, at least locally, confining pressure must have been almost entirely absent. The planar arrangement of vesicles in the natural coke and the manner in which the drag folds of the middle zone are deformed suggest that lateral pressure was greater than vertical." and "(therefore) pressure is not considered to be of major importance in the Absher area." Perhaps, though, even a slight pressure change at the contact would play some part in the behavior of the chlorite at elevated temperatures.

Lastly, the difference between the rate of heating of the shale in the laboratory and the time the shale was held at a given temperature in nature must be of significance in accounting for differences in their diffraction effects. This can be seen in the results of the laboratory heating for, as mentioned earlier, heating for 110 minutes at 450° C produced an x-ray diffraction trace very

similar to one obtained from a 15 minute heating at 480° C. Clegg (1955) also stated that the dike probably cooled relatively slowly due to the low conductivity of the country rock. Had the dike been intruded at a lower temperature and cooled very slowly, the same clay mineral changes in sample D-6 might still have been produced. Clegg's D.T.A. data, though, show that the coal within 6 inches of the dike contact was heated to at least 480° C, yet the same D.T.A. effects would probably be produced if the coal were heated to a slightly lower temperature and held for some time. Rogers *et al.,* (1962) have shown that at and below 400° C lignite held at fixed temperatures will show a decrease in volatile content and an increase in B.T.U.'s with time. D.T.A. changes of the material would also be expected with time.

Sosman (1938) also places a lower limit of temperature at 480° C. on a similar dike in Pennsylvania based on laboratory coking experiments. Clegg (1955) has shown that most of the olivine of the dike has been altered to serpentine. Bowen and Tuttle (1949) stated that the water necessary to convert olivine to serpentine must come from outside of the igneous body and that water will be driven in from the country rock as the olivine cools to approximately 500° C and lower. Clark and Fyfe (1961) stated, "It has been noted frequently that ultrabasic rocks seldom show thermal effects at their contacts, which might be anticipated from their melting temperatures." ". . . the demand for water imposed by the serpentine reaction in chilled marginal phases may cause flow of water into the cooling magma and an abnormally low heating effect at contacts. This situation is in direct opposition to that with granitic rocks where internal water requirements are small, and transfer of water out from the magma may heat contact rocks." Whether the serpentine formed at the time of intrusion or later is not known in this case. If it had been formed at the time of intrusion, though, the inflow of water into the dike would probably have cooled the contact rock rapidly, thus diminishing the possibility of long-term low temperature alteration of the contact zone. If the serpentine formed later and if the dike cooled slowly, approximately 450° C would seem to be the minimum contact temperature from the clay mineral evidence.

Based on the clay mineral changes noted in the partly included shale pieces and in the laboratory heated samples of the unaltered shale, and on the field relationships of the rocks in question, the suggested contact temperature for the dike with the country rock at the time of intrusion is estimated at approximately 450° C to 480° C.

Acknowledgments

The author is indebted to Professors Ralph E. Grim and Carleton A. Chapman, both of the University of Illinois, and to many staff members of the Illinois State Geological Survey for having read and criticized this manuscript.

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DIFFERENTIATION OF SOME PENNSYLVANIAN UNDERCLAYS BY THEIR CLAY MINERAL COMPOSITION

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Ordinary field methods are of little value in local identification of some underclays of the Caseyville, Abbott, and Spoon Formations of Pennsylvanian age in Mercer, Henry and Rock Island Counties of northwestern Illinois. The lateral lithologic variation of some beds, the lenticular nature of others, and the thickness variations of the stratigraphic units make identification difficult.

Differences have been detected in the clay mineral content of some of the underclays. Where stratigraphic data are inconclusive, the differences in mineral composition could help

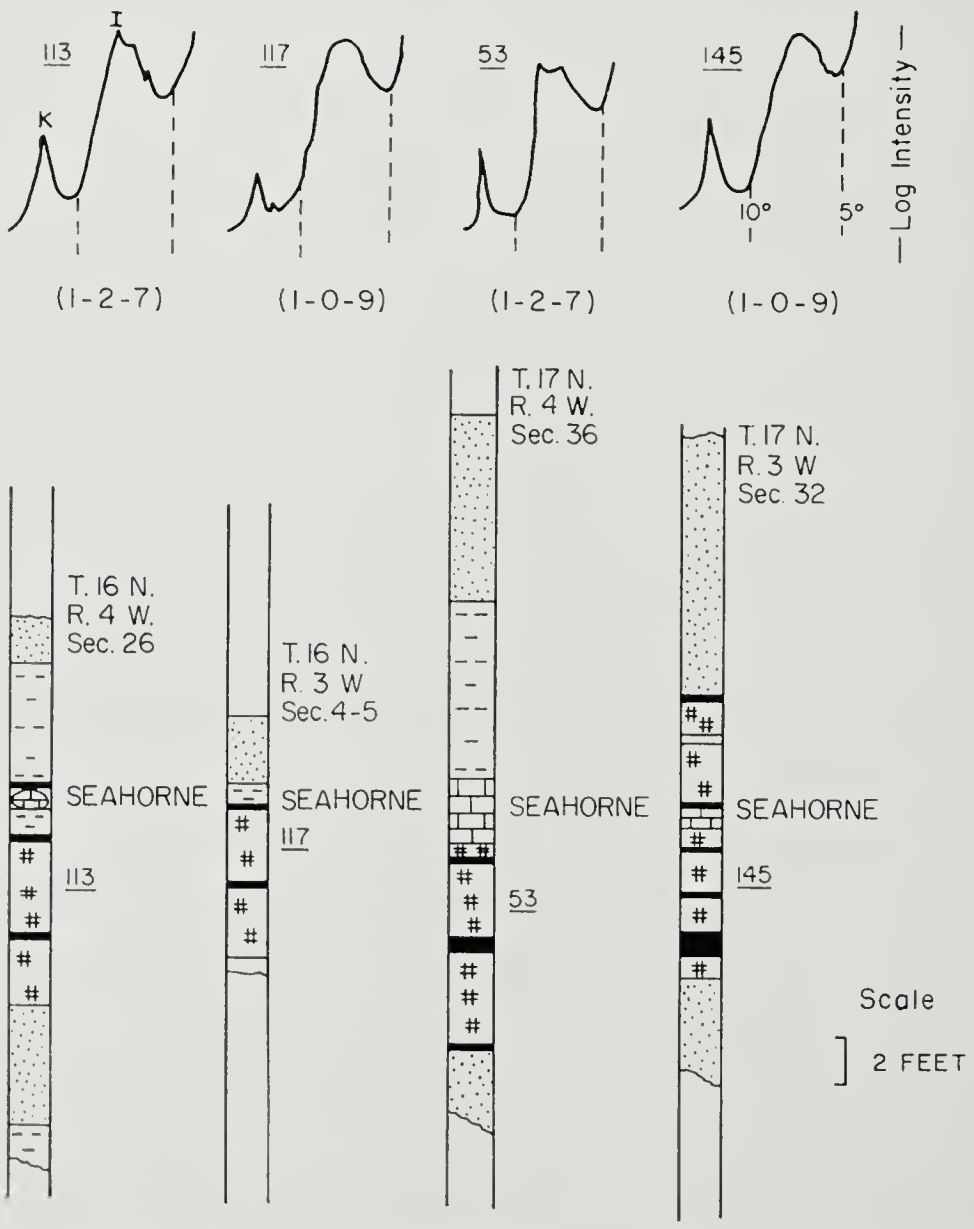

FIGURE 1.—X-ray traces (glycolated) of underclay below the Seahorne Limestone and columnar sections showing position of samples of underclay from Rock Island County.

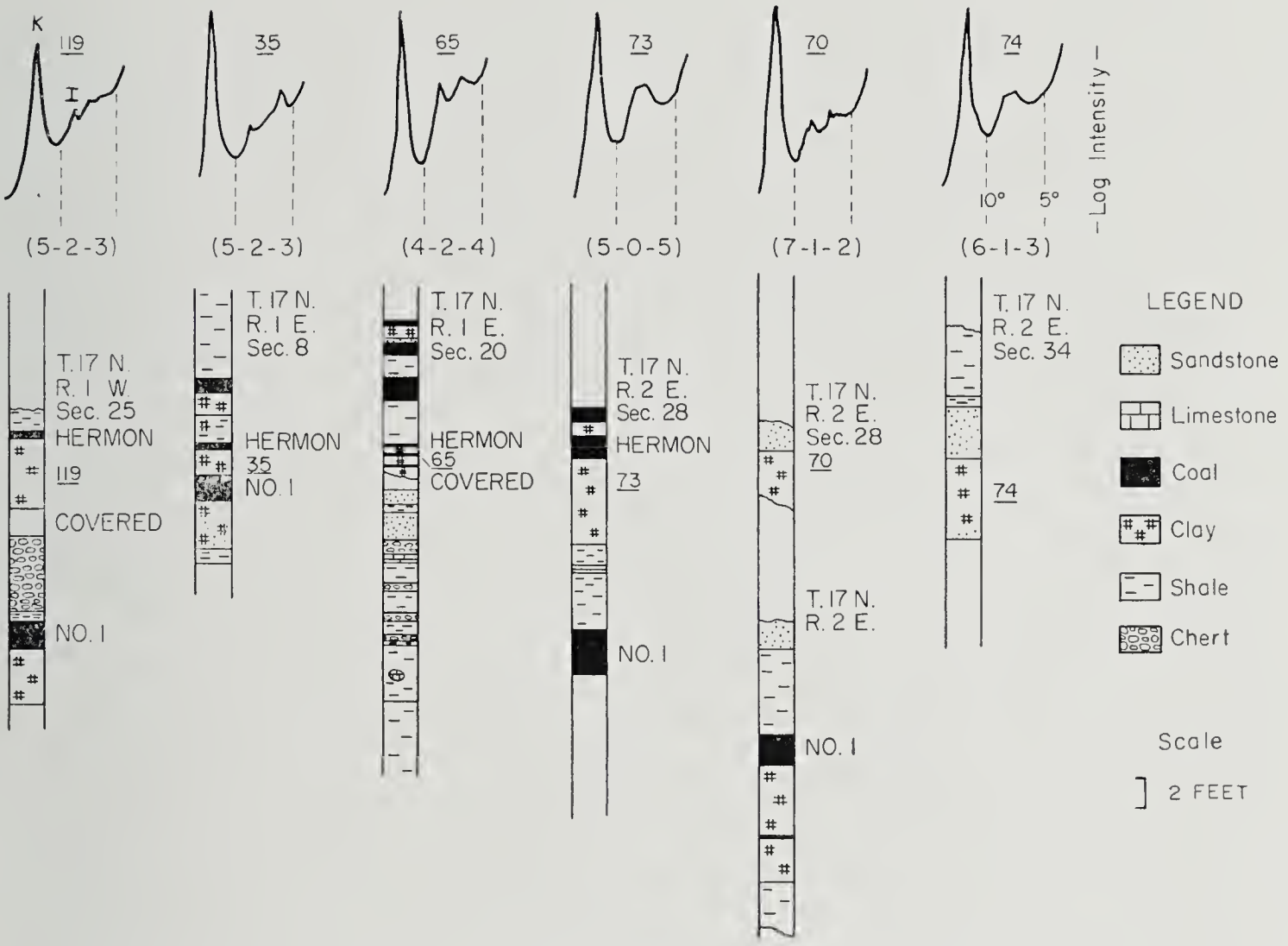

FIGURE 2.—X-ray traces (glycolated) of underclay below the Hermon Coal and columnar sections showing position of samples of underclay from Henry County.

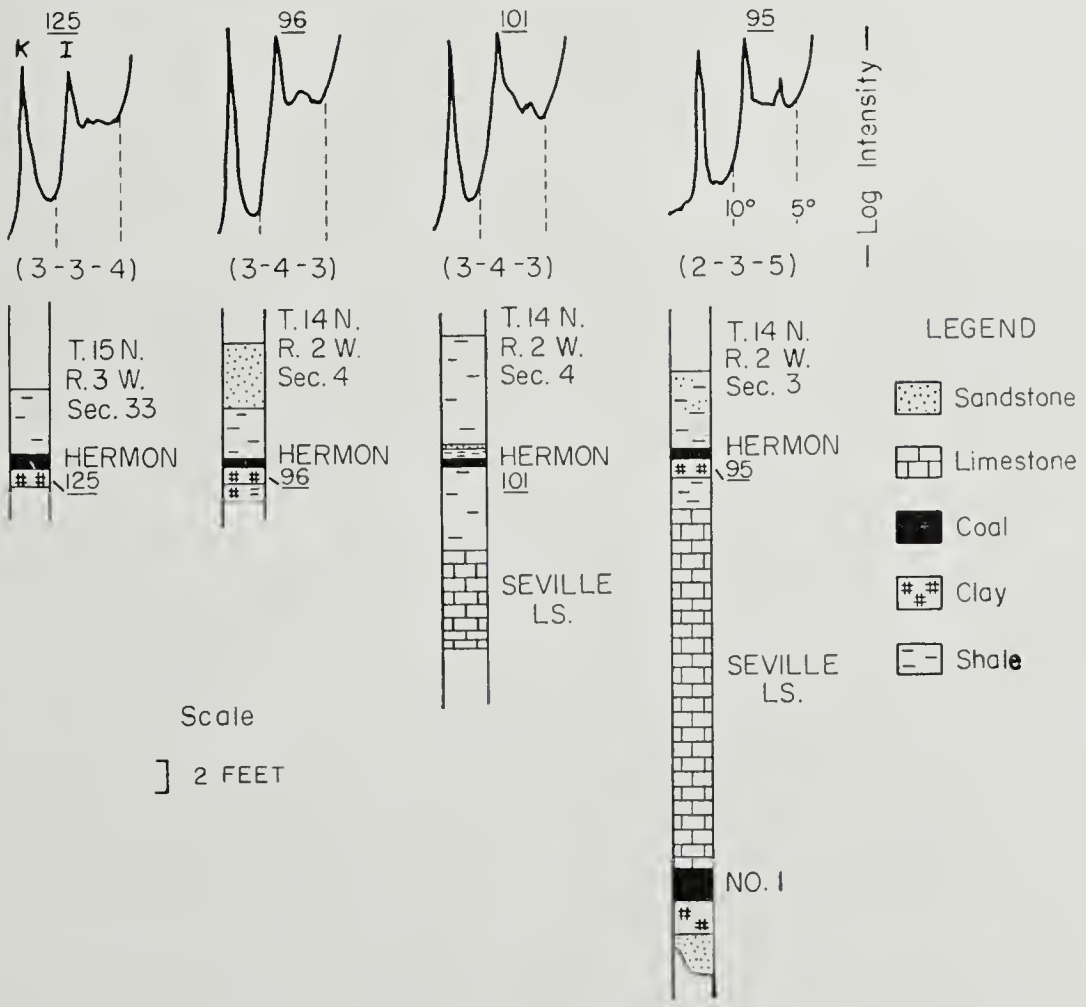

FIGURE 3.—X-ray traces (glycolated) of underclay below the Hermon Coal and columnar sections showing position of samples of underclay from Mercer County.

to identify the stratigraphic position of an underclay.

Method

Sampling in the three counties was limited to the upper third of the underclay outcrops, which range in thickness from a few inches to several feet.

The clay mineral composition of the underclay samples was determined by X-ray diffraction. The $< 2\ \mu$ clay fraction was prepared for analysis by oriented aggregate techniques and was saturated with ethylene glycol. X-ray diffraction patterns of saturated samples are shown in Figures 1 to 4.

The clay mineral composition of the underclays is given in terms of the abundance (parts in ten) of kaolinite, illite, and mixed-layer clay minerals, in that order. An under-

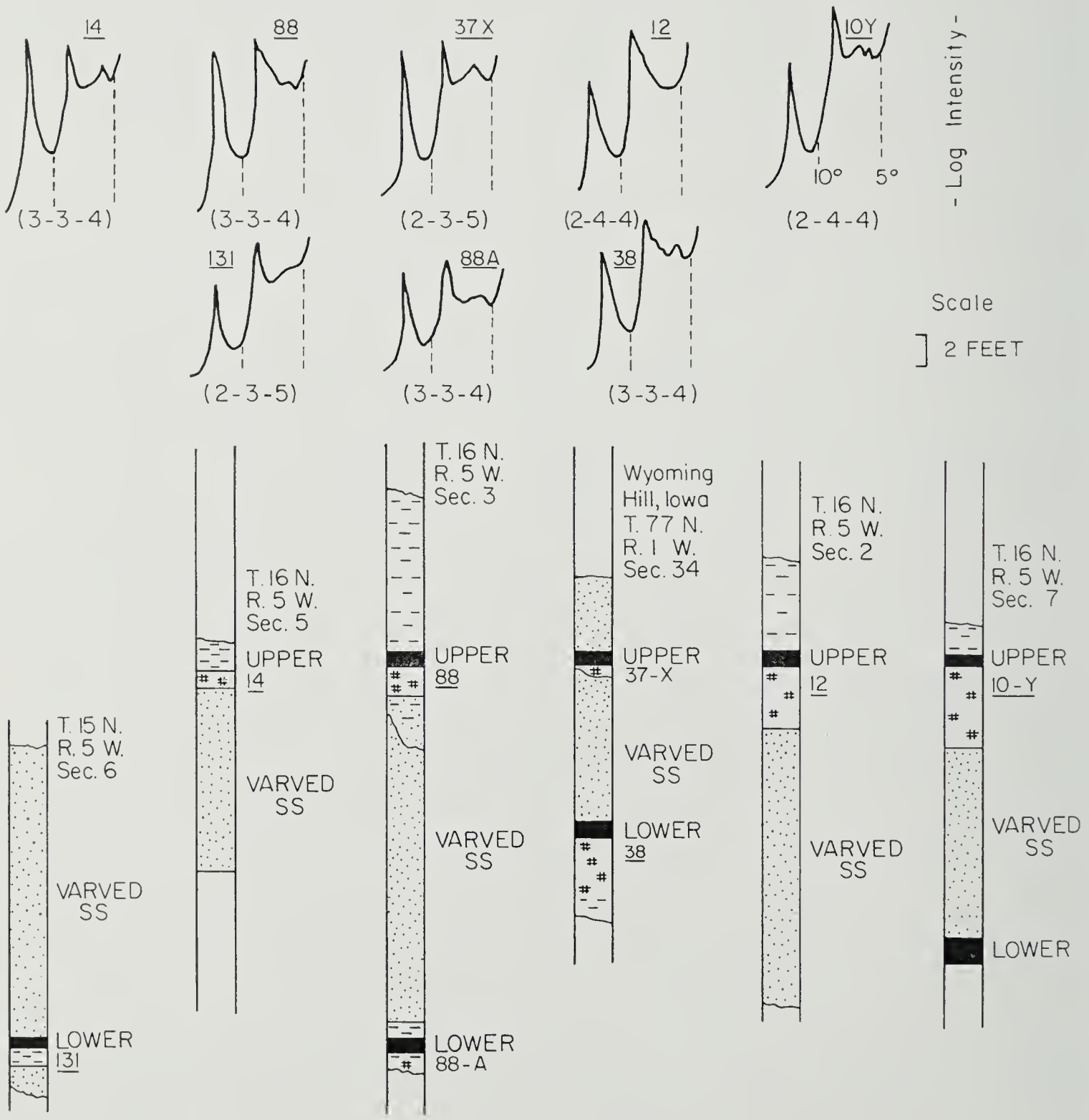

Figure 4.—X-ray traces (glycolated) of underclay below the Caseyville Coals and columnar sections showing position of samples of underclay from Rock Island County.

clay with a composition of 5-2-3, for instance, contains 5 parts kaolinite, 2 parts illite, and 3 parts mixed-layer minerals in 10 parts of $< 2\ \mu$ clay fraction. These values were determined by integrating the area under each first order diffraction peak (kaolinite, 12.4°2θ; illite, 8.8°2θ; mixed-layer material, 5-8.8°2θ) and dividing the first order peak value by the total area represented by all clay minerals present.

Discussion

If the clay mineral composition of any particular underclay varies greatly within a few square miles, it has little value in stratigraphic identification. However, if it can be demonstrated that the clay mineral composition is distinctive and consistent within that area, the composition may help to identify the underclay.

Identification is made in the following manner. The clay mineral compositions of a number of underclays of known stratigraphic positions in a small area are analyzed and particular note is taken of each underclay having a clay mineral composition that is distinct from all other underclays of different stratigraphic position. The rock sequences above and below the underclays are then observed so that both clay mineral and stratigraphic data can be used to characterize a particular underclay. If an underclay of unidentified stratigraphic position is then found in the same small area where underclays of identified position were sampled, and if the clay mineral composition and stratigraphic sequence above and below the unidentified underclay are similar to those of an identified underclay, then the unknown underclay can be identified.

Some of the underclays of the Caseyville, Abbott, and Spoon Formations were found to have distinctive clay mineral compositions. Three different groups of clay mineral assemblages were observed. The characteristic clay minerals, the abundance of kaolinite, illite, and mixed-layer material, and the stratigraphic position of each underclay group are as follows:

Group I—High kaolinite, low illite; low mixed-layer clay minerals; 5-2-3 ratio. *E.g.* underclay of Hermon Coal (Henry County).

Group II—Kaolinite; illite; mixed-layer clay minerals; 3-3-4 ratio. *E.g.* underclay of Hermon Coal (Mercer County). Underclay of coals in Caseyville Formation (Rock Island County).

Group III—Low kaolinite; low illite; high mixed-layer clay minerals; 1-1-8 ratio. *E.g.* underclay below Seahorne Limestone (Rock Island County).

Underclay Below the Seahorne Limestone (Rock Island County)

Underclays were sampled at two localities (Fig. 1, samples 53 and 145) in Rock Island County where the Seahorne Limestone indicates their stratigraphic position. They have a characteristic average clay mineral composition of 1-1-8 (Group

III), which is different from that of all other underclays in the area.

The presence of limestone nodules a few feet above underclay sample 113 (Fig. 1) suggests that this underclay also may lie under a thin coal below the Seahorne Limestone. The fact that sample 113 has a clay mineral composition of 1-2-7, which is similar to the composition of the underclays of known stratigraphic position mentioned above, corroborates the position of sample 113.

The stratigraphic position of sample 117 (Fig. 1) could not be identified positively in the field, although a position below the Seahorne Limestone is suggested by its occurrence slightly below the same elevation of nearby outcrops of flat-lying Seahorne Limestone. As sample 117 has a clay mineral composition of 1-0-9 (Group II, III), very much like the compositions of samples 53, 145, and 113, the possibility that it also may occupy a position under the coal below the Seahorne Limestone is strengthened.

Underclay of the Hermon Coal (Henry County)

The underclay of the Hermon Coal in Henry County has a distinctive clay mineral composition of 5-2-3, which was determined from samples 119 and 73 (Fig. 2). The striking feature of this underclay is its high kaolinite content. In no other underclay studied in this region was kaolinite so abundant.

Samples 35, 65, 70, and 74 (Fig. 2) were of unidentified stratigraphic position. Sample 35 was taken at the head of a small stream, at the mouth of which the Rock Island (No. 1) Coal crops out. As the clay of sample 35 lies slightly higher in the stratigraphic section than the Rock Island Coal, it possibly occurs below the Hermon Coal. In this case, however, stratigraphic information alone was not quite sufficient for identification. The x-ray traces of the unidentified clay were compared with those of underclays already known to occur below the Hermon Coal and were found to belong to the same group. Although the clay mineral composition alone was not definite evidence of position, in cases such as this it adds weight to the evidence provided by stratigraphic data.

Parham (1962) observed that the clay mineral composition of a particular underclay may vary from place to place, in some instances changing from Group I to Group III within a short distance. The use of clay mineral composition for identification, therefore, is valid only in small areas where the variation is known to be minor. For example, the underclay of the Hermon Coal varies only slightly in a distance of seven miles from the position of sample 119 to the position of sample 73, and underclays with abundant kaolinite within this area probably can be considered to lie under the Hermon Coal. The clay below the Seahorne Limestone also varies very little in a distance of about four miles (from the location of sample 145 to the location of sample 117), making it probable that clays with a composition approximately 1-1-8 in this small area lie below the coal under the Seahorne Limestone.

Underclays of the Hermon Coal (Mercer County) and Two Underclays in the Caseyville Formation (Rock Island County)

Although a distinctive clay mineral composition may be useful in identifying a particular underclay, underclays of two different stratigraphic positions may have similar clay mineral compositions different from those of all other underclays in the area. Clay mineral composition is still useful in identification in such cases for confirming available stratigraphic data.

The underclay of the Hermon Coal in Mercer County (Fig. 3) and the underclays of two unnamed coals (Fig. 4) all have a composition of approximately 3-3-4 (Group II). Robert M. Kosanke (personal communication, 1961) has found spores from these unnamed coals that are similar to spores from coals in the Caseyville Formation of southern Illinois, and the coals, therefore, are presumed to be from the Caseyville Formation. The two coals are separated by approximately 10 feet of varved, tan sandstone, which is a good marker bed. As no stratigraphic names have yet been applied to these coals, they will be referred to here as the coal above the sandstone (upper coal) and the coal below the sandstone (lower coal).

The underclays of the Hermon Coal in Mercer County lie above a marker bed — the Seville Limestone. The Hermon Coal lies approximately 100 feet above the two coals in the Caseyville Formation. Although the clay mineral composition of the three underclays is similar, the compositions are still valuable in distinguishing among them when sufficient stratigraphic information is not available. For example, samples 125 and 96 (Fig. 3) were taken from two outcrops where no distinctive marker bed was present. The composition of these samples was approximately 3-3-4 (Group II), which indicates that they are definitely below either the Hermon Coal in Mercer County or the Caseyville coals. Numerous outcrops of known stratigraphic position of the flat-lying Hermon Coal occur near and at the same elevation as samples 125 and 96, whereas in this area coals in the Caseyville Formation lie 100 feet below the Hermon Coal. Thus, it is reasonable to assume that samples 125 and 96 are from the underclay of the Hermon Coal. Here the clay mineral data furnished a clue to the stratigraphic position of the underclay and the stratigraphic information substantiated this position. Used separately, neither set of data offers sufficient evidence for identification; used together, they offer a reasonably certain stratigraphic identification.

Summary

Clay mineral composition, determined by X-ray diffraction, may be a useful supplement to stratigraphic data in identification of underclays.

The characteristic clay mineral composition of an underclay of known stratigraphic position must first be identified. If the clay composition of the identified underclay remains reasonably consistent in a

small area, it may then be compared with the clay composition of an underclay of unidentified stratigraphic position within that same area. If the clay mineral compositions of the underclays are similar and there is reasonable similarity in their stratigraphic position, the underclays can be assumed to be the same unit.

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Manuscript received March 2, 1963.

PRELIMINARY NOTES ON A NEW METEORITE FOUND NEAR WOODBINE, ILL.

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The town of Woodbine is in Jo Daviess County, Illinois, about 7 miles west of Stockton. While plowing in the spring of 1953, Mr. Henry Albrecht, whose farm is located a mile west of Woodbine, discovered a rusty, metallic "boulder" buried about 8 inches beneath the surface of the ground. This object, measuring about 8 x 12 x 13 inches, was kept in the farmyard as a curiosity. Some loose pieces were detached and given away. One of these pieces was taken to the Geology Department at Beloit College by Mr. Tyler Bastian, a student. It was sectioned, and correctly identified as a meteorite, by Professor Henry H. Woodard. In June, 1961, the writer learned of this discovery through correspondence with Dr. Woodard. A trip to the Albrecht farm resulted in the recovery of the main mass.

Thanks are due to Mr. Albrecht, Mr. Bastian, and Dr. Woodard for their assistance in making the meteorite available for study. Financial support came from the National Science Foundation under Research Grant G-18669. Dr. E. P. Henderson of the U.S. National Museum has offered constructive suggestions concerning the manuscript.

The main mass, when brought to Lawrence College, weighed 48.2 kg. A slice weighing 2.27 kg was cut off to reveal the internal structure. Both

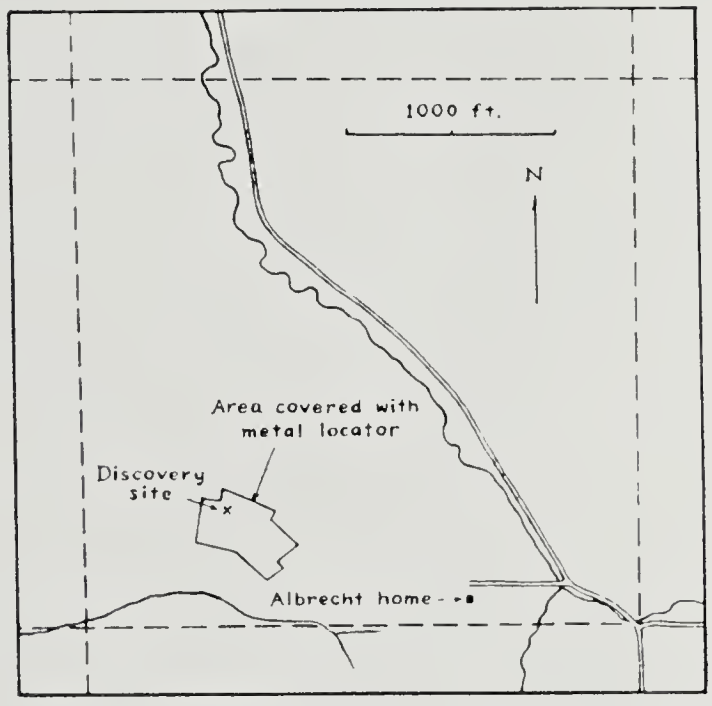

FIGURE 1.—Southeast quarter of Section 9, T 27 N, R 3 E., Jo Daviess County, Illinois. Cross indicates discovery site. The town of Woodbine is located one mile east of the Albrecht home.

the slice and the remainder of the main mass are now in the U.S. National Museum. Of the fragment originally given to Mr. Tyler Bastian, Beloit College has 24.7 g. The rest (77.4 g) has been returned to Mr. Albrecht. Nothing is known of the whereabouts of the other small fragments which were given away.

DESCRIPTION OF SITE

The Albrecht farm is located mainly in the SE ¼ of Section 9, T 27 N, R 3 E., Jo Daviess County. This is maturely dissected country drained by tributaries of the Apple River. Vertical relief is around 200 ft. The

precise discovery location is indicated in Figure 1. Here the ground slopes southward from the crest of a divide between two streams. Several old gullies on the slope have been filled with boulders and other debris, later covered with soil. It is possible that the meteorite may have been transported from some other location by an earlier occupant of the farm and dumped into one of the gullies. The writer's efforts to locate additional buried fragments in the vicinity by means of a specially constructed metal detector (Read, 1962) were unsuccessful.

Coordinates of the discovery location are Lat. 42° 20′ 48″ N; Long. 90° 10′ 3″ W. This is favorable ground for future detector work since it is in the Driftless Area and magnetic glacial boulders are lacking.

External Form

Four views of the exterior of the meteorite are shown in Figure 2. In general, the shape is that of an angular block only slightly modified by atmospheric ablation. It seems probable that the original bolide broke

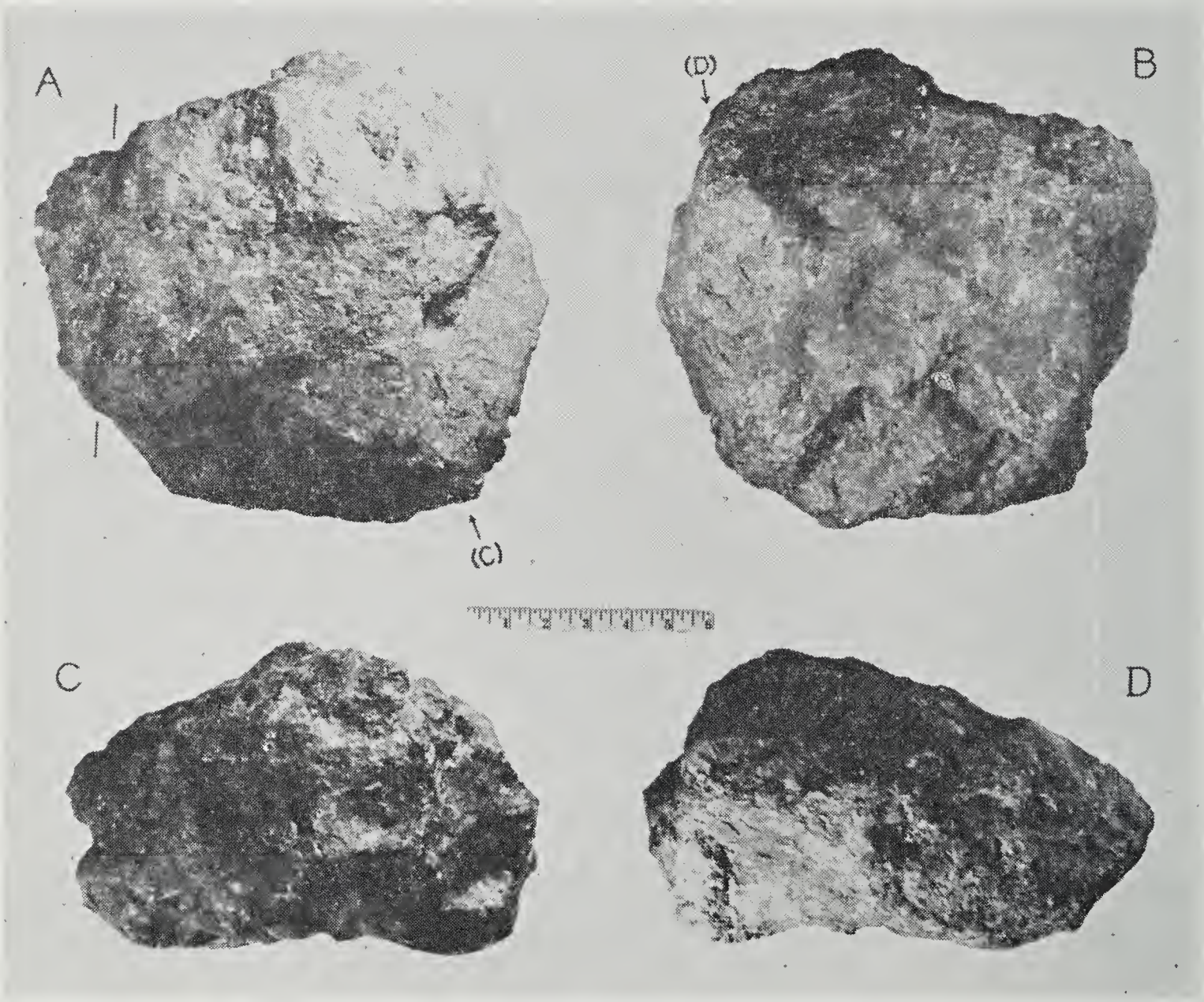

Figure 2.—Exterior views of the Woodbine meteorite. Scale reads in inches. A and B are opposite sides. Camera directions for C and D relative to A and B indicated by arrows. The short lines adjoining A show location of saw cut for surface illustrated in Figure 3.

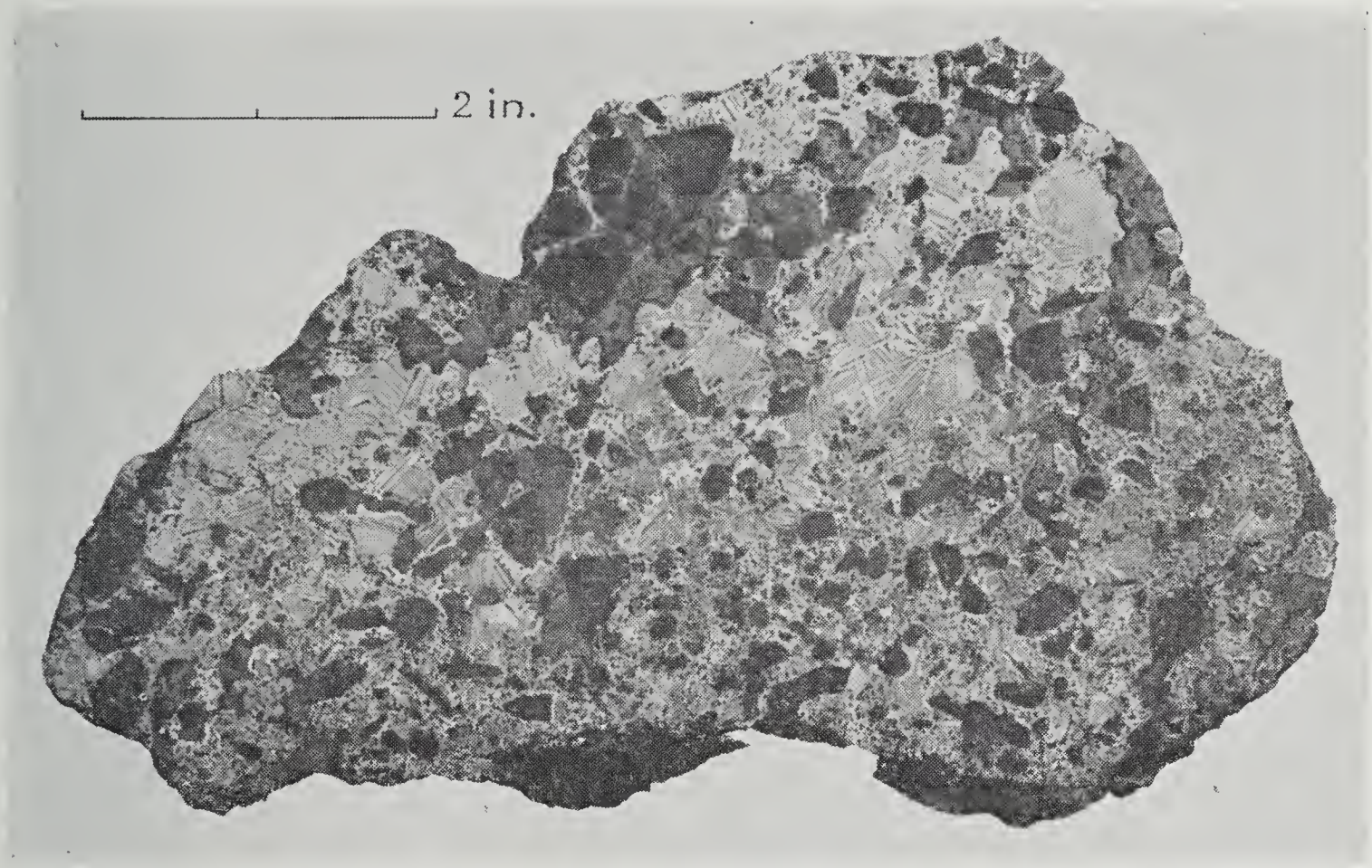

FIGURE 3.—Etched surface of the Woodbine meteorite. Stony fragments appear nearly black. Adjoining dark grey areas are mainly troilite, plus a little schreibersite. Nickel-iron is light grey, with crosshatching. Two thick remnants of the weathered crust (appearing black) are present on the lower edge.

up at a fairly high level in the atmosphere and that other pieces of it lie yet undiscovered in the Woodbine area. The original fusion crust and its detailed flight markings have been obliterated by weathering. The principal ablation features now remaining are the characteristic shallow pits known as regmaglypts. A number of these, closely spaced, may be seen near the bottom of surface A. Three or four large pits, somewhat irregular in shape, appear on the lower half of surface B, and there are others of the same kind on surface C. The remaining surfaces lack clearly defined depressions of this type. Possibly they were exposed, by rupture, so late during passage through the atmosphere that ablation had little time to operate on them. There is nothing in the overall shape of the meteorite, or in the form and arrangement of the regmaglypts, to suggest oriented flight.

On the right side of surface A, Figure 2, there is a notch about 6 inches long, 2 inches wide, and an inch or two deep. According to Mr. Albrecht, this is the place from which the loose pieces were detached. One surface of the notch (brightly illuminated in fig. 2a) is fairly flat, suggesting a fracture. There is some indication that the opposing vertical surface is also fracture-controlled—probably by more than one fracture. All surfaces of the notch are now heavily rust-coated and were probably in this condition when the loose pieces were broken away.

Composition

Figure 3 shows the appearance, after polishing and etching, of the flat surface of the slice cut off at Lawrence College. In general, it exhibits about 30% stony fragments, 10% troilite (FeS), and 60% nickel-iron. These percentages are based on Rosiwal analysis.

The weathering crust is now a mere film around most of the etched surface. However, on the lower edge as shown in Figure 3 there are patches as much as 6 mm in thickness. It seems likely that the entire specimen had a crust of this or greater thickness when first dug up and that all but a few remnants were flaked off during subsequent handling on the farm. Hairline veinlets of limonite penetrate well into the interior. A conspicuous example follows the inner border of the string of troilite extending down from the upper right edge in Figure 3. Here oxidation penetrates to a depth of 4 cm.

Fractures can be seen cutting across stony fragments in the upper and lower right corners in Figure 3. These fractures continue through patches of troilite but disappear in the nickel-iron.

The stony fragments are of a fairly uniform dark brown color. The largest encountered in the plane of sectioning has a measurable maximum diameter of 18 mm. As shown by the photograph, the fragments tend to be distinctly angular. Their contacts with surrounding metal are not truly sharp, however, but minutely spongiform, suggesting incipient replacement by the metal. Some of the smaller fragments appear to have had their angularity considerably reduced by this process.

Composition of the stony material appears to be fairly uniform — a mosaic of tiny silicate grains interspersed with fine disseminated nickel-iron and sulfide. Occasional crystals up to 2 mm in diameter are visible, more abundantly in some fragments than in others. Chondritic structures, if present, are not easily recognized.

Isolated silicate grains, or small groups of grains, occur both in nickel-iron and in troilite. Some of these may represent dissolved material later rejected by the metallic phases. Others may simply be last remants of thoroughly absorbed inclusions.

Troilite commonly surrounds groups of the stony fragments. In addition, troilite patches show a fairly marked tendency to be connected. Thus, an irregular, branching "vein" of troilite may be seen extending down from the upper right edge in Figure 3. It is possible that the series of troilite patches extending to the left from this edge are, or were, connected beyond the plane of the section.

That the sulfide, as well as nickel-iron, has replaced silicate inclusions is clearly indicated by the condition of the large stony fragment just to the right of the big notch in the top edge as shown in Figure 3. In addition, contacts between troilite and nickel-iron have an embayed appearance strongly suggesting replacement of the former by the latter. "Headlands" of troilite are in some instances capped by small stony fragments which appear to have protected the sulfide from attack. If

so, replacement of silicates by nickel-iron must have been a slower process than replacement of troilite. In a few places, troilite and nickel-iron are separated by a band of schreibersite (Fe_3P) ½ to 1 mm wide. Where schreibersite is present, evidence of replacement of the sulfide is lacking.

Within the troilite, a faint light-dark color variation can be discerned. Lighter material tends to surround darker, or cut through it along hairline veinlets. Apparently the lighter phase is of later origin. It may be the result of recrystallization to a coarser grain size.

In addition to the borders around troilite, mentioned above, schreibersite occurs in small patches attached to the larger stony inclusions or surrounding clusters of tiny ones. The total amount of schreibersite present is less than 1%.

As in the case of the Four Corners meteorite which is also highly charged with stony inclusions (Merrill, 1924), the nickel-iron is divided into a large number of distinct grains with different crystallographic orientations. Each grain has a continuous border of kamacite (the low-nickel component) approximately 1 mm in width. Within this border the usual Widmanstätten figure is evident. Typical kamacite bands are only about ½ mm in width —tapering toward their extremities. Thin strips of plessite (undifferentiated nickel-iron) with taenite (high-nickel) borders are commonly present between adjoining parallel bands. Larger plessite "fields" of triangular or quadrangular shape occur between bands running in different directions. The thin strips etch black. Small fields show black margins and brownish-grey interiors. The larger fields usually contain segregated strips of kamacite, either in very fine lamellae paralleling the coarser bands outside the fields or in more or less irregular dendritic growths.

The largest individual grains of nickel-iron encountered in the plane of sectioning measure about 15 mm in diameter. These appear in the upper half of the photograph, Figure 3. Toward the bottom of the photograph, where stony fragments are more closely spaced, the grains are correspondingly smaller.

After several days of exposure to the atmosphere, the uncoated etched surface showed small patches of fresh rust, mainly around some of the stony inclusions and areas of schreibersite. These indicate the presence of lawrencite ($FeCl_2$).

Summary

The Woodbine meteorite is the fifth reported from the state of Illinois. It is a rare type, characterized by the presence of abundant angular stony fragments between which the nickel-iron has crystallized in different orientations. The best-known other example of this type is the Four Corners meteorite from New Mexico.

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THE VARIATION METHOD AND THE TWO-ELECTRON MODEL

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The Variation Method (Eyring, *et al.*, 1944, p. 99) has been used by chemists in energy calculations. For problems where a two-electron approximation is made and inner shells are ignored, care must be taken in the use of the Variation Method. The primary purpose of this paper is to investigate whether these two-electron calculations are a variation problem with respect to two-electron energies or a perturbation problem.

The investigation considers the usual two-electron Hamiltonian as a perturbed case of a more general two-electron Hamiltonian. The results of the present calculations with the generalized Hamiltonian should be considered as a demonstration rather than a general proof since specific wave functions are used. These results are compared to those of a usual two-electron calculation of LiH and Li_2 recently given by Harriss, Mitchell, and Musulin (1963).

James (1934) performed calculations, for Li_2 with a modified six-electron Hamiltonian, using all six electrons and using, also, a two-electron approximation. The results indicated that the serious underestimation of the binding energy with a complete calculation was corrected for by the approximation of neglect of inner shells. That is, the omission of inner shells neglects a repulsive potential due to these inner shells. This, in turn, leads to a smaller value for the equilibrium internuclear distance. In general, the Heitler-London (1927) method leads to values of the binding energy which are too low and values of inner shell repulsion which are too high.

The generalized two-electron Hamiltonian, referred to above, may be considered as one which neglects, in two-electron calculations, all screening by the inner shells. Consequently, by comparison with the results of the usual two-electron calculation, it should be possible to obtain an estimate of the inner shell repulsions. It is proposed that this method of obtaining the repulsions is an alternate method to that of James.

The Hamiltonian

The two-electron Hamiltonian for the two-center problem is

$$\mathbf{H} = -\frac{1}{2}\nabla_1^2 - \frac{1}{2}\nabla_2^2 - \frac{Z_a}{{}_1r_a} - \frac{Z_a}{{}_2r_a} - \frac{Z_b}{{}_1r_b} - \frac{Z_b}{{}_2r_b} + \frac{1}{r_{12}} + \frac{Z_aZ_b}{R} \qquad (1)$$

where Z_i is the nuclear charge of the i^{th} center, r_{12} is the interelectronic distance, ${}_jr_i$ is the distance between center i and electron j, and R is the distance between the centers. The Hamiltonian is given in atomic units (a.u.) (Energy: 1 a.u. = 27.210 e.v.; Charge:

1 a.u. = 4.80286 x 10^{-10} e.s.u.; Mass: 1 a.u. = 9.1083 x 10^{-28} g; Length: 1 a.u. = 0.529172 x 10^{-8} cm.).

In the usual Heitler-London approximation, the inner shell electrons are considered to be too close to the nucleus to actually take part in chemical reactions. This has the effect, in problems involving the lithium atom, of giving Z_i the value 1 instead of 3. In the present calculations, Z_i, where it involves a lithium atom, will be given the value 3. That is, it is assumed that the inner shells do not screen the nucleus at all.

Since

$$\frac{3}{{}_jr_i} = \frac{2}{{}_jr_i} + \frac{1}{{}_jr_i}$$

then

$$\mathbf{H} = \mathbf{H}_o + \mathbf{H}' \qquad (2)$$

where $\mathbf{H}$ is the Hamiltonian used in the present calculations, $\mathbf{H}_o$ is the usual two-electron Hamiltonian, and $\mathbf{H}'$ is the perturbing Hamiltonian, containing terms $2/{}_jr_i$.

The Wave Function

In order to thoroughly test the model, the calculations are performed with two types of atomic wave functions. The first type is the usual noded wave functions which are solutions of the hydrogen atom problem (Eyring, *et al.*, 1944, p. 89). The second set consists of the nodeless functions proposed by Slater (1930). The molecular wave function is described by the usual LCAO (linear combination of atomic orbitals) approximation in its simplest Heitler-London form. That is, only 1s orbitals are used for the hydrogen electron and only 2s orbitals for the valence lithium electron.

Eyring, *et al.* (1944, p. 216) have also shown how the exact solutions of the hydrogen atom problem may be modified and taken in linear combinations to approximate the exact solutions of molecular problems. One of the modifications which they mention is that of placing a multiplicative factor in front of the distance parameter in the exponential portion of the wave function. Through the years it has been customary to use values suggested by Slater (1930) for this multiplicative factor.

The Slater terms are obtained from values of screening in the atomic case. These, of course, are not properly valid when an atom takes part in molecular formation. However, the mathematical processes necessary to correct the situation have been so laborious that workers in the field have usually neglected the error resulting from the use of the Slater values. Since these values are based upon atoms, it appears to be suitable to describe them by the adjective atomic. Furthermore, in recent years, it has become recognizable that some of the attempts to identify these multiplicative factors with physical quantities, such as screening, are rather nebulous in the very complex wave functions being tested on today's high-speed computers. Consequently, the general categorical term, orbital parameter, has become adopted. The word, orbital, is used as part of the description insomuch as the quantum number is also part of the single, compound, multiplicative factor of the distance parameter (Eyring, *et. al.*, 1944, p. 89). Combining these terminologies, it may be said that

workers in the past have used wave functions with an atomic orbital parameter.

Musulin (1956) has shown how, for diatomic molecules, an orbital parameter, which varies with internuclear distance, may be obtained. This functional dependence is more realistic for molecules than the use of a fixed value as determined by Slater (1930). In line with the terminology of the preceding paragraph, Musulin has used the adjective, molecular, to describe his multiplicative factor. The whole term is referred to as a molecular orbital parameter. The present work uses a molecular orbital parameter in all wave functions.

The necessary constants defining the orbital parameter are computed with the following three electron groupings: (1) all electrons (4 in the case of LiH and 6 for Li_2); (2) only valence electrons in the presence of unscreened nuclei; (3) only valence electrons in the presence of completely screened nuclei. Technically, it might be better to describe the third grouping by saying "in the presence of partially screened nuclei" since Slater's (1930) rules are used to determine the orbital parameters for the united and separated atoms. However, the terminology used allows for easier tabulation.

Calculation Details

The usual techniques are used to obtain explicit expressions for all integrals except the exchange integral. Insomuch as several approximations have already been made, the Mulliken (1949) approximation is more *apropos* to the problem.

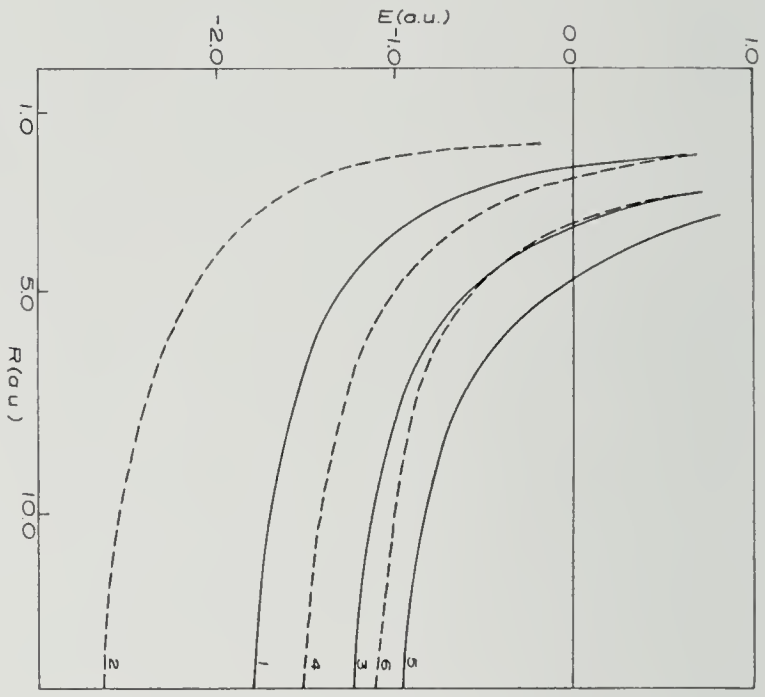

Figure 1.—Potential energy curves of Li_2. Key: 1, 2—six-electron orbital parameter; 3, 4—unscreened two-electron orbital parameter; 5, 6—screened two-electron orbital parameter; solid line—hydrogen-like wave functions; and dashed line—Slater wave functions.

The calculations were performed upon an IBM 650 computer having no extra storage. The original programs were written in Fortran and

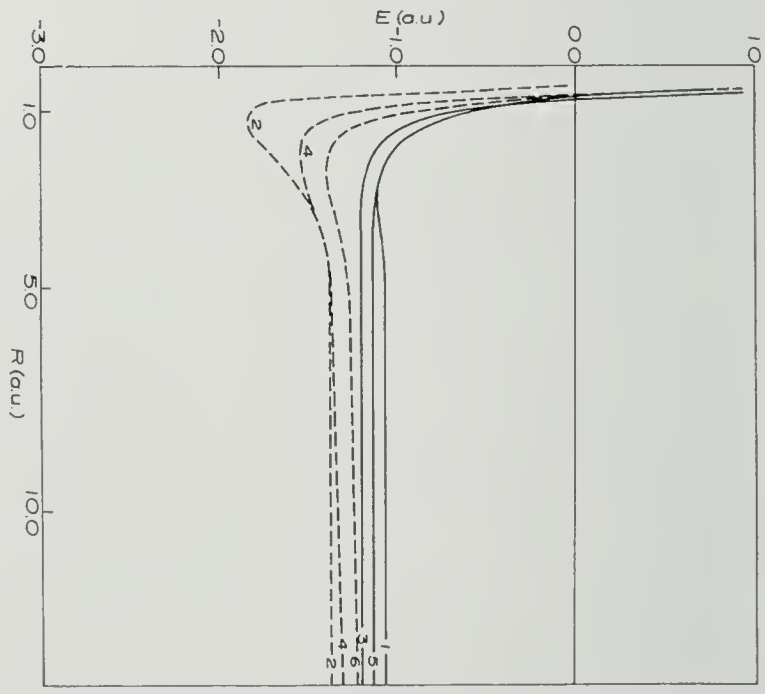

Figure 2.—Potential energy curves of LiH. Key: 1, 2—four-electron orbital parameter; 3, 4—unscreened two-electron orbital parameter; 5, 6—screened two-electron orbital parameter; solid line—hydrogen-like wave functions; and dashed line—Slater wave functions.

the corrected versions were written in Illiad (1961). The integrals were evaluated at 70 points of R between the values of 0.25 and 50.00 a.u. The greatest density of points was taken at the experimental internuclear distance (Herzberg, 1950).

The experimental values of electron energies, dissociation energies, and internuclear distances were obtained from Herzberg (1950) and Moore (1949). The calculated dissociation energies are obtained by taking the difference between the energy at the equilibrium distance and the asymptote.

Results

The potential energy curves obtained for Li_2 are given in Figure

Table 1.—Summary of Spectroscopic Results for LiH.

Function	Orbital Parameter	R_e(a.u.)	−E(a.u.)	D_e(a.u.)	$\triangle D_e$(a.u.)
Hydrogen-like	Four-electron average	2.80	1.1058	0.0531	0.0091
	Two-electron average	4.00	1.2157	0.0298	—0.0064
	Two-electron average with screening	4.75	1.1447	0.0197	—0.0083
Slater	Four-electron average	1.25	1.8653	0.5038	0.1567
	Two-electron average	1.75	1.5537	0.2576	0.0614
	Two-electron average with screening	2.20	1.4021	0.1938	0.0287
Experimental		3.01	0.793* 8.072**	0.095	

* Two-electron.
** Four-electron.

Table 2.—Summary of Test Criteria for LiH.

Function	Orbital Parameter	Virial Theorem	Occupation Numbers
Hydrogen-like	Four-electron average	0.68	0.7379
	Two-electron average	0.68	0.7577
	Two-electron average with screening	0.68	0.7560
Slater	Four-electron average	0.48	0.7279
	Two-electron average	0.48	0.8758
	Two-electron average with screening	0.47	0.8733

1 and the corresponding curves for LiH are given in Figure 2. The values for LiH, of the equilibrium internuclear distance, R_e, the total energy, E, at R_e, and the dissociation energy, are summarized in Table 1. No binding was observed in Li_2 for any of the six trial wave functions.

Table 2 lists the results of evaluating the present wave function for LiH by two different criteria. These results are included to insure that the wave function is of the same degree of "goodness" in calculations using both types of Hamiltonians.

The first criterion results from the use of the Virial Theorem (Slater, 1933). In Table 2, values of the ratio (-2 kinetic energy/potential energy) are presented at the equilibrium distance. According to the Virial Theorem, this ratio should have the value of 1.0 at this distance.

The second of these test criteria is the use of occupation numbers. The transformation given by Shull (1959) is used to transform the present wave function into a truncated two-term Natural Spin Orbital expansion. The square of the coefficient of the first term of the expansion is the occupation number, of that term, which should be very close to unity if the truncated expansion is a good approximation to the true expansion.

Discussion

Each of the total energy values obtained in the present calculations for LiH is below the total experimental two-electron energy. This is an apparent contradiction of the Variation Theorem. However, the results may be explained by a consideration of the restrictions of the Variation Theorem.

In the Variation Method, an "exact" Hamiltonian is used with approximate wave functions. On the other hand, in the Perturbation Theory, an approximate Hamiltonian is used with eigenfunctions which are exact solutions of that Hamiltonian. The Hamiltonian given by equation (1) is the "exact" Hamiltonian for a two-center, two-electron problem if the values of Z_i are correctly defined. In the present calculation, it is unrealistic to believe that the valence electrons are under the forces of unscreened nuclei. Consequently, it should not be expected that the Variation Theorem provides a lower bound for the total energy.

If this same argument is applied to the usual two-electron calculation, a similar conclusion must be reached. The assumed value of $Z_i = 1$ is also unrealistic. In fact, the valence electrons are under the influence of a partially screened nuclear field of $Z_i = 3$ (if the i^{th} center is the Li atom). Thus, one should question whether or not it is proper to state that values obtained in the usual two-electron calculations are bounded from below by the experimental two-electron energy.

If the usual two-electron calculations are considered as perturbation calculations, then the energy obtained may be either above or below the experimental energy. The usual consequence of the Variation Theorem is that a value obtained below the experimental energy is the result of a numerical error or a failure of the model selected.

It should be pointed out that the present calculation, as described in equation (2), is not a true perturbation calculation since the LCAO wave functions are not eigenfunctions of $\mathbf{H}_o$. However, one could recast the Hamiltonian so that the problem appears as a true perturbation problem. This is done by splitting $\mathbf{H}_o$ into two parts, viz.,

$$\mathbf{H}_o = \mathbf{H}_o' + \mathbf{H}_o''$$

where $\mathbf{H}_o'$ is the Hamiltonian for a composite system of hydrogen-like atoms and $\mathbf{H}_o''$ contains the remainder of the terms of $\mathbf{H}_o$. The LCAO functions are then solutions of $\mathbf{H}_o'$, and the problem could be treated rigorously as a perturbation problem.

In the present calculations, if total energy is used as a criterion to select the best wave function, it is seen that the use of a hydrogen-like function, with a molecular parameter determined by the use of all four electrons, provides the best LCAO approximation to the wave function of LiH.

Since no binding was found for Li_2, it would not be appropriate to discuss whether or not the total energy at the stable minimum is above or below the experimental two-electron energy. On the other hand, if one examines the total energies obtained at the experimental internuclear distance, one finds that five of the six calculations yield values below the experimental energy value.

The Variation Theorem does not provide any information on bounds of dissociation energies. It might be noted that the hydrogen-like wave function, with a molecular orbital parameter using all four electrons, again provides the best value of the dissociation energy.

The essential difference between this calculation and that performed by Harriss, *et al.*, is the addition of the perturbing term, $\mathbf{H}'$, of equation (2). This term is attractive in nature and has the effect of lowering, for a given internuclear distance, the total energy. Physically, the difference corresponds to the shielding of the nuclear field by the inner shell electrons. In this framework, it might be said that the traditional two-electron calculation corresponds to the inclusion of inner shells (the assigned value of $Z_i = 1$ in the Hamiltonian corresponds to complete shielding by the inner shells) while the present calculation corresponds to the omission of inner shells. It is to be noted that this does not imply that inner shells are included in any two-electron calculation.

The results obtained, using this viewpoint, agree with those given by James. The inclusion of inner shells gives rise to a repulsive potential in the ground state of Li_2. The present calculation also indicates that this is true for LiH. However, with the present wave function, all binding is lost when the inner shells are omitted in Li_2. Thus, the binding energy is greater with the inner shells included, which is contrary to the results of James. It would appear that the use of a wave function with a molecular orbital parameter causes the repulsive potential due to inner shells to be as great or greater at large distances than at equilibrium distances; whereas, the James' wave function causes this potential to greatly diminish at large distances.

For the ionic, LiH molecule, the dissociation energy is greater with the omission of inner shells in four of the six calculations. This is indicated by the results tabulated in the final column of Table 1, which of course then are the inner shell repulsions.

Some readers may find the purely mathematical approach of the present work, and that of James (1934), too mysterious. They may be reassured that the results are similar to those obtained in *a posteriori* arguments by chemists who base their work upon experimental evidence. For example, Pitzer (1948) concludes qualitatively, based upon experimentally determined dissociation energies, that inner shells repel each other. Pitzer indicates that such repulsions are not as predominant for first row species (including Li_2) as for species of other rows in the periodic table. The present paper can make no such comparisons, but the values of Table 1 and those found by James indicate that neglect of inner shell repulsions may cause a misestimate of the binding energies of the outer electrons by as much as 40 to 60%.

The strong shifting of equilibrium distances toward smaller values found by James is not found in the present calculation. A slight indication of this effect is found, for LiH, if the orbital parameter in hydrogen-like wave functions is determined using all four electrons. It is this selection of wave function which must be considered best, if agreement with the work of James is used as a criterion.

The hydrogen-like wave functions are found to be better using the Virial Theorem criterion. However, they do not appear to be as satisfactory a function as when used with the traditional two-electron Hamiltonian.

The occupation number criterion indicates that the Slater wave functions are the better, although the difference in values is not as great as with the Virial Theorem criterion. A second point is that there is almost no change in the values of occupation numbers when the calculation is performed with the different Hamiltonians.

It would appear that there is not much difference in the "goodness" of the wave function in the calculation with the two Hamiltonians. Therefore, the conclusions concerning inner shell repulsion, based upon the use of these functions, are internally consistent.

Summary

Calculations made in the Heitler-London approximation, using a molecular orbital parameter, for Li_2 and LiH support the contention that the energy values obtained from a traditional two-electron calculation are not bounded by the experimental two-electron energy. A new method, considering the usual two-electron calculations as a perturbation problem, is introduced for interpreting the repulsion due to the inner shells. Calculations are given to estimate the amount of these repulsions.

Acknowledgment

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Corporation whose funds enabled the author to purchase a desk calculator which made some of the numbers possible.

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THERMODYNAMIC PROPERTIES OF P_4

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The theromdynamic functions of $P_4(g)$ calculated by Thyagarajan and Cleveland, (1960; 1961) were based upon frequencies corrected semiquantitatively for anharmonicities (Pistorius, 1958) which resulted in approximate zero order frequencies. A more accurate set of functions is obtained if the fundamentals rather than zero order frequencies are used in the rigid-rotor harmonic-oscillator approximation. This results in a partial correction for the anharmonicities (Herzberg, 1945). The functions in Table 1 are based upon the assignment of Gutowski and Hoffman, (1950) and a P-P bond distance of 2.21°A. (Maxwell, Hendricks and Moseley, 1955).

A third law entropy of 66.9 ± 0.2 cal. deg.$^{-1}$ mole^{-1} at 298.15°K. results from the calorimetric (Maples, 1949) and vapor pressure (Dainton and Kimberly, 1950) measurements in good agreement with the statistical value obtained with the fundamentals. The use of the approximate zero order frequencies leads to a value of 66.4 (Thyagarajan and Cleveland, 1961).

TABLE 1. Functions Derived from Fundamental Frequencies.

T°K	cal. mole^{-1} deg.$^{-1}$			kcal. mole^{-1}
	C°_P	S°	$-(F^\circ-H^\circ_{298.15})/T$	$H^\circ-H^\circ_{298.15}$
0	0.000	0.000	Infinite	—3.378
100	8.899	53.486	79.150	—2.566
200	13.294	61.010	68.285	—1.455
298.15	16.051	66.893	66.893	0.000
300	16.088	66.992	66.893	0.030
400	17.510	71.837	67.544	1.717
500	18.281	75.835	68.814	3.510
600	18.735	79.212	70.273	5.363
700	19.022	82.123	71.763	7.252
800	19.214	84.676	73.221	9.164
900	19.348	86.947	74.622	11.093
1000	19.445	88.991	75.958	13.033

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SOME RECORDS OF THE MEADOW JUMPING MOUSE (*ZAPUS HUDSONIUS*) FROM SOUTHERN ILLINOIS

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The meadow jumping mouse (*Zapus hudsonius*) is rarely taken in southern Illinois. Two specimens have been recorded from Union County by Layne (1958:249). Gersbacher and Swayne (1951:122) report two taken in Perry County in April, 1948, and one taken in Jackson County in July, 1940. Despite active collecting by students and faculty from Southern Illinois University, no additional specimens of *Zapus* were taken in Jackson County until recently.

In 1962, extensive trapping in the summer resulted in the capture of eight specimens of *Zapus*; the first specimens of this genus to be taken in Jackson County since Gersbacher and Swayne reported their capture. Two additional captures represent a new county record for Franklin County and another specimen from Union County.

To attest to the rarity of capture of the species in this area, only five specimens were obtained during a trapping study which ran continuously from January to October, 1962. One hundred snap-traps were placed in a grid pattern in an old field three-fourths of a mile southwest of the Life Science Building on the Carbondale Campus. Ten lines of ten traps each were spaced at approximately 25-feet intervals. The five specimens were taken one each after 16,800 trapnights (January 6 to June 25); 18,200 (July 10); 19,100 (July 19); 22,700 (August 24); and 26,200 (ending September 28) trapnights. No additional specimens were taken from September 29 to October 8, after which the line was discontinued. All the above specimens of *Zapus* were captured near a small ditch south and west or east of the dam of a pond less than 1/10th-acre in size on the trapping area. All were taken within 75 feet of the pond. The cover at the trapsites was sparse, with little litter on the ground, and was dominated by young sassafras (*Sassafras varifolium*) trees 10 to 20 feet tall.

Additional specimens of *Zapus* were obtained by 3 of 20 students enrolled in a course in mammalogy offered by Dr. E. Lendell Cockrum. The sixth record for Jackson County was taken on June 23 by Arthur Hicks the first night that 20 traps were set! These examples indicate the extremely sporadic nature of capture. The specimen taken by Mr. Hicks was trapped on the botany reserve along an old barbed-wire fence row under a willow tree (*Salix nigra*) approximately 20 feet tall. The ground was devoid of vegetation and litter, but abundant cover of trumpet creeper (*Campsis radicans*) surrounded the spot of capture. Mr. Hicks had traps in this

campus area for more than a month and failed to catch another specimen. Walter Biggs caught two specimens behind the high school building in Murphysboro, Jackson County, in late July.

The specimen from Franklin County, an adult male, was taken two miles north of West Frankfort on July 14 by Larry Contri. All these specimens are now part of the collection of the Zoology Department at Southern Illinois University.

From 1959 to 1963 a class from the Department of Zoology has placed 250 to 500 mousetraps overnight each year in the Pine Hills area north of Ware in Union County, Illinois. The number of traps set and the date each year were as follows: 250 on June 5, 1959; 300 on May 20, 1960; 400 on May 26, 1961; 250 on June 1, 1962; and 500 on May 24, 1963. In this total of 1450 trapnights over five years, only one *Zapus* was taken. This specimen, taken in 1963, was an adult female trapped in the wooded bottomland near the base of the bluff at Pine Hills.

Inasmuch as *Zapus* goes into hibernation during the winter, no records would be expected to be obtained at this time. Available records in southern Illinois span the period from April to October. Fitch (1958: 161) notes that jumping mice are particularly elusive to live-trapping. Most of his captures were in unbaited funnel traps set for reptiles. Thus, evasiveness may partially explain the few specimens on record in southern Illinois. The more probable reason for lack of records is that little trapping has been done during the summer months when the animals are most active.

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DISTRIBUTIONAL NOTES ON ARIZONA MAMMALS

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Specimens in the collections of the Museum of Natural History, University of Illinois, and certain ones recently examined by us in other collections, provide some new or corrected records of mammals for Arizona and are worthy of recording.

Dipodomys spectabilis clarenci: This species and subspecies definitely occurs in the northeastern part of Arizona. Specimen no. 262999, ♀, U. S. National Museum, Biological Survey Coll., collected by Luther Goldman at 8 miles south of Chin Lee (= Chinle), Apache County, is referable to this subspecies. Cockrum (1960 [= 1961]) and Hall and Kelson (1959) give no indication of any *D. spectabilis* from northeastern Arizona but Miller and Kellogg (1955, p. 390) correctly ascribe this subspecies to this area.

Dipodomys spectabilis perblandus: This subspecies occurs as far north in Arizona as Florence, Pinal County. Two specimens (145387, 145390) in the American Museum from this locality are referable to this subspecies. At Florence, and only here as far as we know, both species of large kangaroo rats, *Dipodomys spectabilis* and *D. deserti*, occur together. Specimens recorded as *D. spectabilis* from more northern localities by Clothier (1960, p. 517) are referable to another species, *Dipodomys deserti arizonae*.

Perognathus penicillatus sobrinus: There is considerable question that this species has previously been taken in the northwest corner of Arizona (see beyond). Thirteen specimens (13448-13454, 19419-19424) from Beaver (Dam) Lodge, 1900 feet, Mohave County, are in the collection of the Museum of Natural History, University of Illinois.

The type locality for this subspecies is given as "sand flat along Virgin River, 7 miles above Bunkerville", in Nevada. The type specimen of *P. s. sobrinus* (U. S. Nat. Mus., 27598/39697) is labeled "Bunkerville, Nevada, May 9, 1891. Death Valley Expedition", and it is so entered in the museum catalogue. Bailey's catalogue has for the type specimen (his number 2743) "Virgin River Valley, Nevada, 7 miles above Bunkerville, May 9, 1891. Sand Flat along river." This information has been checked by Dr. Richard H. Manville, to whom we are grateful. Seven miles in a straight line would put the collecting site in Arizona although by a circuitous route, it might very well have been in Nevada. Hardy (1949) regarded the type locality as being in Arizona. Since Bailey indicated Nevada on his label and in his catalogue, and since it is so entered in the Museum catalogue, one must assume for now that the type locality is in Clark County, Nevada, but near the Nevada-Arizona line. Nevertheless, it

is evident that this subspecies does occur in extreme northwestern Arizona.

Perognathus parvus trumbullensis: The species *P. parvus* has not been recorded south of Mt. Trumbull in Mohave County, Arizona. Five specimens (19641-19645, Univ. Ill.) are now available from as far south as the slopes of Mt. Dellenbaugh, Mohave County.

Eutamias quadrivittatus quadrivittatus: This subspecies is represented from the northeast part of Arizona by specimens from the following localities: *Apache County*: 4 mi. S, 3 mi. W Sawmill, 6 (U.I.); 6 mi. S, 3 mi. W Sawmill, 1 (U.I.); Sawmill 4 (U.S.B.S.); summit Lukachukai Mts., 8,000 ft., 15 mi. E. Lukachukai Navajo School, 8 (U.S.B.S.); Wheatfield Creek, W slope Tunitcha Mts., 7,000 ft., 2 (U.S.B.S.); summit Tunitcha Mts., 8,000 ft., 1 (U.S.B.S.); near head Spruce Creek, 9,000 ft., Tunitcha Mts., 3 (U.S.B.S.); Spruce Creek, 8,000 ft., Tunitcha Mts., 1 (U.S.B.S.).

The bright-colored subspecies *Eutamias quadrivittatus hopiensis* probably does not occur east of the type locality (Keams Canyon, Navajo County). Actually, topotypes of *E. q. hopiensis* are intergrades with *E. q. quardrivittatus* (see also White, 1953, p. 570).

Sciurus aberti: Abert's squirrels are present in the Hualpai Mountains. They were introduced there, according to William Musgrove, about 1933. In 1955, they were holding their own and we collected a specimen (8791) from the north side of Hualpai Peak at 8700 feet elevation. It is not known to us if these squirrels ever lived there naturally.

Acknowledgment

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FREQUENCY DISTRIBUTION OF HILL PRAIRIE PLANTS

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Little remains today of the original prairie vegetation of Illinois described by Weaver (1954) and mapped by Vestal (1931). Study of remaining patches becomes increasingly difficult as prairie areas are engulfed by urbanization. While our floristic knowledge of prairie vegetation is considerable (Evers, 1955), more knowledge of spatial and successional relations of the vegetation are needed. Many undisturbed hill-prairies provide an adequate community for these studies. These prairies, dry grasslands on hills and bluffs bordering the Mississippi and Illinois Rivers, although areally restricted (usually less than an acre in extent), are geographically widespread throughout the state. This paper adds information about the spatial relations of the plants of one of these prairies. One of the largest of this type of prairie in the state occurs at the top of a south facing slope of a bluff bordering the Illinois River in Pere Marquette State Park, SE ¼ Sec. 9 T. 6 N., R. 13 W., Jersey County, Illinois. The slope of the prairie varied from 26 to 36 per cent. The soil, derived from a wind-blown loess, ranged from 50 to 65 per cent silt plus clay.

Methods of Study

All data came from a 30-meter square laid out in the middle of the prairie. The plot was subdivided into 900 square quadrats, one meter on a side. In each of these quadrats were placed several smaller square quadrats of the following sizes: ½ meter x ½ meter $(m/2)^2$; dm^2, cm^2, and a point. The $(m/2)^2$ quadrat was placed at random in this m^2 quadrat, and the smaller quadrats were nested within a regular fashion. Each frequency figure is based on 900 sample points, although only ninety of the quadrats were used for cover estimation.

The frequency figures, and the frequency curves, are based on two features: first, the rooted occurrence of the species; and second, on rooting and/or coverage alone of a portion of the quadrat. In other words, for coverage determination, foliage presence above the quadrat was sufficient for it to be considered present for frequency purposes.

Results

A total of 65 plant species were observed in the plot. These included 3 mosses, 1 lichen, 1 gymnosperm and 60 flowering plants. Of this assortment, only 6 species of grass were found, despite the fact that grasses completely dominated the herbaceous vegetation. The dominant grass species was *Andropogon scoparius,* a feature consistent with other hill prairies (Evers, 1955). Table 1 shows that coverage of this

single species exceeded that for all other plants combined. The other species were rooted between the clumps of this grass.

The high coverage values of *A. scoparius,* plus the consistent presence of this plant throughout the plot, resulted in high frequency values for the larger quadrats as shown by Table 2. Note that the frequency values for all species decrease as the size of the plot decreases and that the rooted values are consistently lower than the coverage values. Figures 1 and 2 illustrate these frequency values graphically.

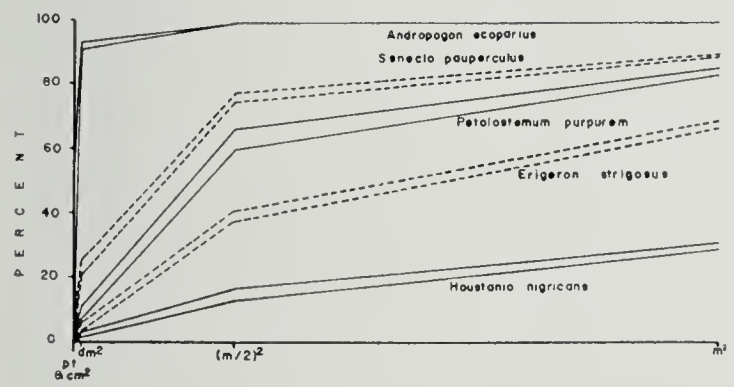

FIGURE 1.—Frequency curves for selected common prairie plants. Upper line represents frequency values based on coverage; lower line based on rooting.

TABLE 1.—Percent of Plant Coverage in 90 m² Quadrats for those with Coverage 0.2 percent or more.

Species	Percent Cover
Andropogon scoparius	53.5
A. gerardi and *Sorghastrum nutans*	3.1
Bouteloua curtipendula.....	1.6
Houstonia nigricans	1.6
Senecio pauperculus.....	1.0
Solidago nemoralis.....	0.9
Erigeron strigosus.....	0.7
Petalostemum purpureum..	0.7
Desmodium sessilifolium...	0.4
Kuhnia eupatorioides.....	0.2
Dermatocarpon hepaticum..	0.2

Several species were discovered that did not appear on the list of hill-prairie plants recorded by (Evers, 1955). The more common species that apparently favor the hill-prairie habitat are listed in Table 3.

DISCUSSION

The data show correlation between frequency and coverage in that those plants with the largest coverage also possess the highest frequency values. The exceptions occur with small

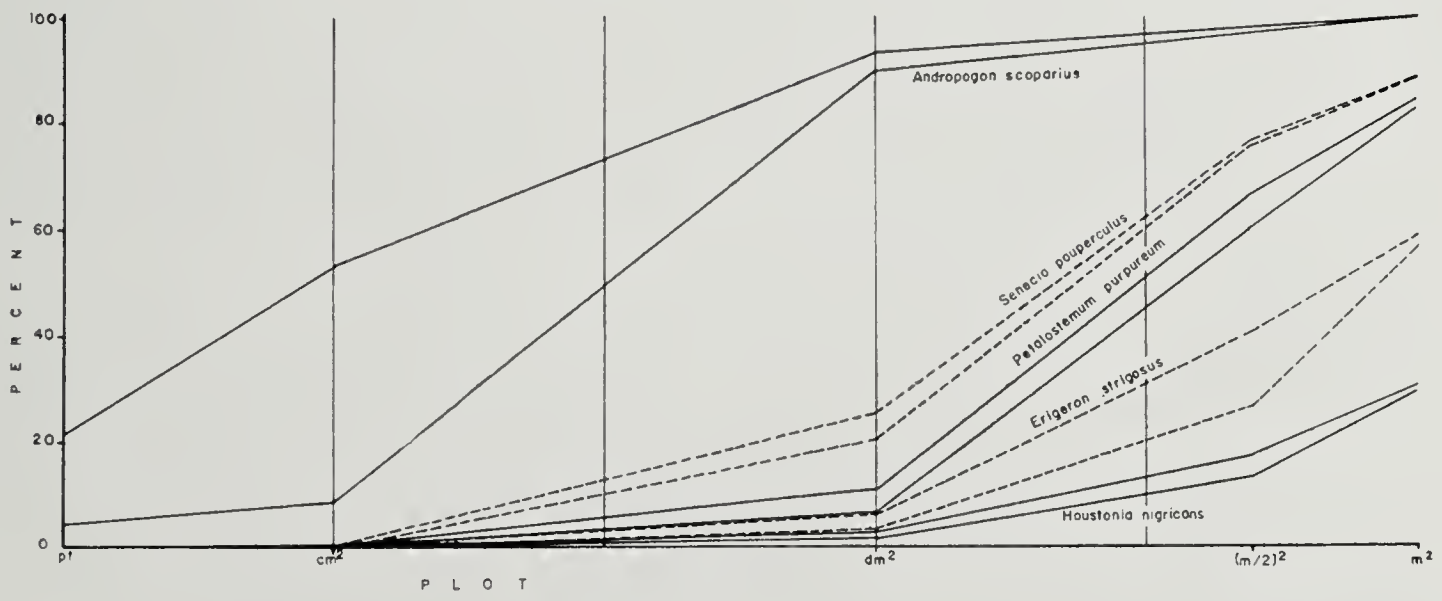

FIGURE 2.—Frequency curves for selected common prairie plants plotted on semi-logarithmic scale. Upper line represents frequency values based on coverage; lower line based on rooting.

TABLE 2.—Frequency Distribution of Most Common Plants by Quadrat Sizes for Rooted Plants (R) and Covered (C).

Species		Quadrat Size pt.	cm^2	dm^2	$m/2^2$	m^2
Andropogon scoparius	R	4.6	8.6	90.6	99.8	100
	C	21.3	53.4	93.4	99.8	100
Sorghastrum nutans & *Andropogon gerardi*	R	0.1	0.3	36.2	86.5	95.3
	C	1.0	3.2	40.4	88.2	96.6
Senecio pauperculus	R	0.0	0.0	20.3	75.9	88.5
	C	0.4	0.6	25.7	77.2	88.9
Weisia controversa	R	0.9	0.9	17.0	54.3	87.8
	C	0.9	0.9	17.0	54.3	87.8
Petalostemum purpureum	R	0.0	0.0	7.0	59.4	83.5
	C	0.2	0.3	11.1	66.0	85.5
Dermatocarpon hepaticum	R	1.0	1.7	8.5	39.6	68.9
	C	1.0	1.7	8.5	39.6	68.9
Erigeron strigosus	R	0.0	0.0	3.7	36.6	66.0
	C	0.3	0.7	6.2	40.8	68.9
Desmodium sessilifolium	R	0.0	0.1	3.6	36.3	56.8
	C	0.1	0.3	4.4	38.2	59.4
Houstonia nigricans	R	0.0	0.0	1.7	13.3	28.8
	C	0.1	0.3	3.4	17.0	30.6

TABLE 3.—Common Species from Pere Marquette Prairie not Listed by Evers (1955). Figures are Rooted Frequencies Based on 900 m^2 Quadrats. Nomenclature According to Jennings, 1951 (moss), Fink, 1935 (lichen) and Fernald, 1950 (vascular plants).

Species	Frequency of occurrence
Moss	
Weisia controversa	87.8
Lichen	
Dermatocarpon hepaticum	68.9
Vascular Plants	
Asclepias hirtella	0.7
Desmodium paniculatum	2.2
Lespedeza violacea	0.3
Spiranthes gracilis	3.3
Verbascum thapsus	2.2

plants such as *Weisia* and *Dermatocarpon* which have high frequency values, but little coverage. Conversely, large plants like *Kuhnia,* which have considerable coverage, have a spotty distribution and low frequency of occurrence.

Table 2 illustrates the dependence of frequency values on quadrat size, well illustrated by Cain and Castro (1959) and Evans (1952) and shows that the selection of optimum quadrat size can maximize frequency variation and provide more information. In this plot the dm^2 quadrat gives the widest range of values for the most common species.

The frequency curves illustrate the data in Table 2 graphically. The variability of these curves makes construction of a mathematical frequency equation difficult, yet this would be a far more desirable way to illustrate frequency data than a single frequency figure. The curves of very frequently occurring species show sharp breaks in the smaller quadrats, and an almost linear line over the larger values (fig. 1). This break disappears when the curves are drawn on semilogarithmic paper (fig. 2), and indicates that frequency log-area plotting should prove far more useful in detailed analysis of this relation.

Summary

This investigation revealed several additional features about the structure and composition of hill prairie vegetation. Little bluestem (*A. scoparius*) is the species with highest frequency and coverage values in this prairie. Seven heretofore unreported prairie species are added to the floristic hill prairie list of Evers (1955). The frequency values for all plants increased with quadrat size, but the coverage values were higher or equal to the rooted values.

Acknowledgments

The authors express appreciation to the Illinois Department of Conservation and to Mr. Studebaker, Pere Marquette Park Superintendent, for permission to carry out this study in the State Park; to Mr. R. Pursell, Botanist, Penn State School of Forestry, for determination of the mosses; to Dr. Mason Hale, Curator of Cryptogams, Smithsonian Institution, for the lichen determination; and to Dr. Robert Evers, Botanist, Illinois Natural History Survey, for determination of many of the vascular plants.

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A PRELIMINARY CHECKLIST OF FLESHY FUNGI FROM JACKSON AND UNION COUNTIES, ILLINOIS

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The fleshy fungi of southern Illinois have not been studied as much as the flowering plants. McDougall's report (1917) of eleven species from Jackson and/or Union Counties is the only reference we have found concerning the mushrooms of this area. Collections made in the fall of 1962 in Jackson and Union Counties are reported here as a preliminary list (Table 1).

Collection Areas

The principal collecting sites were Giant City State Park, Pine Hills, Midland Hills Woods, and Thompson Point Woods on the campus of Southern Illinois University. Giant City State Park lies in the southeastern part of Jackson County and the north-central part of Union County, Illinois. The topography of

Table 1.—Species of Fleshy Fungi Collected from Jackson and Union Counties, Illinois. An asterisk indicates a species reported by McDougall (1917) from the county(ies) listed.

Auriculariaceae

Auricularia auricula-judae (L.) Berk., Pine Hills, Union Co.

Tremellaceae

Exidia glandulosa (Bull.) Fr., Pine Hills, Union. Co.

Thelephoraceae

Stereum frustulosum (Pers.) Fr. Thompson Point Woods, Jackson Co.
Stereum hirsutum (Willd.) Pers., Midland Hills Woods, Jackson Co.
Stereum versicolor (Schw.) Fr., Midland Hills Woods, Jackson Co.

Clavariaceae

Clavaria stricta (Fr.) Quel. Thompson Point Woods, Jackson Co.

Hydnaceae

Gloiodon strigosus (Fr.) Karst., Pine Hills, Union Co.
Hericium erinaceus (Fr.) Pers., Pomona Road, Jackson Co.

Polyporaceae

Daedalea ambigua Berk., Midland Hills Woods, Jackson Co.
Daedalea confragosa Bolt. ex Fr., Southern Hills Woods, Jackson Co.
Favolus alveolaris (DC. ex Fr.) Quel., Thompson Point Woods, Jackson Co.
Fomes applanatus (Pers. ex Wallr.) Gill., Thompson Point Woods, Jackson Co.
Fomes fraxinophilus (Pk.) Sacc., Thompson Point Woods, Jackson Co.
Merulius sp., Midland Hills Woods, Jackson Co.
Polyporus frondosus Dicks. ex Fr., Thompson Point Woods, Jackson Co.
Polyporus lucidus Leys. ex Fr., Thompson Point Woods, Jackson Co.
Polyporus pargamenus Fr., Giant City State Park, Jackson Co.
Polyporus picipes Fr., Giant City State Park, Union Co.
Polyporus sulphureus Bull. ex Fr., Thompson Point Woods, Jackson Co.
Polyporus versicolor L. ex Fr., Midland Hills Woods, Jackson Co.
Strobilomyces strobilaceus Berk.*, Union Co.

Agaricaceae

White-spored forms:
Amanita pantherina Fr., Giant City State Park, Union Co.
Amanita spreta Pk., Giant City State Park, Jackson Co.
Amanita verna Fr.*, Giant City State Park, Union Co.
Amanitopsis albocreata Atk., Midland Hills Woods, Jackson Co.
Amanitopsis vaginata (Bull.) Roz.*, Jackson and Union Co.
Cantharellus cibarius Fr.*, Jackson and Union Co.
Cantharellus aurantiacus Fr.*, Jackson and Union Co.
Clitocybe illudens Schw., Thompson Point Woods, Jackson Co.
Clitocybe infundibuliformis Fr., Giant City, Jackson Co.; Pine Hills, Union Co.
Clitocybe multiceps Pk., Giant City, Union Co.
Clitocybe ochropurpurea Berk., Midland Hills Woods, Jackson Co.
Clitocybe odora Fr., Midland Hills Woods, Jackson Co.
Collybia alcalinolens Pk., Giant City State Park, Jackson Co.
Collybia delicatella Pk., Giant City State Park, Jackson Co.
Collybia dryophila Fr., Midland Hills Woods, Jackson Co.
Collybia fuliginella Pk., Pine Hills, Union Co.
Collybia radicata Rehl.,* Jackson and Union Co.
Hygrophorus unquinosus Fr., Giant City State Park, Union Co.
Lactarius piperatus Fr.,* Jackson and Union Co.
Lactarius volemus Fr.,* Jackson and Union Co.
Lepiota naucina Fr., Thompson Point Woods, Jackson Co.
Lepiota procera Fr., Thompson Point Woods, Jackson Co.
Marasmius androsaceus Fr., Giant City State Park, Jackson Co.
Marasmius rotula Fr., Midland Hills Woods, Jackson Co.
Mycena clavicularis Fr. var. *luteipes*, Giant City State Park, Union Co.
Mycena haematopa Fr., Midland Hills Woods, Jackson Co.
Panus angustatus Berk., Midland Hills Woods, Jackson Co.
Pleurotus ostreatus Fr.,* Pine Hills, Union Co.
Russula virescens Fr.,* Union Co.
Schizophyllum commune Fr., Thompson Point Woods, Jackson Co.
Tricholoma personatum Fr., Thompson Point Woods, Jackson Co.
Tricholoma resplendens Fr., Giant City State Park, Union Co.
Pink-spored forms:
Pluteus cervinus Schaeff.,* Jackson and Union Cos.
Black-spored forms:
Coprinus atramentarius Fr., Pine Hills, Union Co.
Coprinus comatus Fr., Giant City State Park, Jackson Co.
Coprinus micaceus Fr., Giant City State Park, Jackson Co.
Purple-brown-spored forms:
Agaricus abruptibulbus Pk., Pine Hills, Union Co., Thompson Point Woods, Jackson Co.
Agaricus placomyces Pk., lawn on Skyline Drive, Carbondale, Jackson Co.
Ochre-spored forms:
Cortinarius cinnamomeus Fr., Thompson Point Woods, Jackson Co.
Cortinarius prasinus Fr., Midland Hills Woods, Jackson Co.
Cortinarius privignus Fr., Giant City State Park, Jackson Co.
Hebeloma surjense Karst., Giant City State Park, Union Co.
Hypholoma incertum Pk. var. sylvestris, Giant City State Park, Union Co.
Hypholoma velutinum (Fr.) Quel., Southern Illinois University Campus, Jackson Co.
Pholiota aegerita Fr., Pine Hills, Union Co.

Lycoperdaceae

Calvatia craniformis (Schw.) Fr., Pine Hills, Union Co.
Lycoperdon umbrinum Pers., Pine Hills, Union Co.
Lycoperdon polymorphum Vitt., Pine Hills, Union Co.; Southern Illinois University Campus, Jackson Co.
Lycoperdon pyriforme Pers., Pine Hills, Union Co.

Phallaceae

Mutinus caninus (Pers.) Fr. var. *caninus*, Thompson Point Woods, Jackson Co.

Nidulariaceae

Crucibulum vulgare Tul., Midland Hills Woods, Jackson Co.
Cyathus striatus (Huds.) Hoffm., Midland Hills Woods, Jackson Co.
Cyathus vernicosus Bull., Thompson Point Woods, Jackson Co.

(Saccardo lists four varieties of this species; due to the age of the specimen and absence of peridioles, it is difficult to say what variety is present.)

the park consists of deep, narrow or wide channels cut into massive sandstone rock of Pennsylvanian age overlain by Pleistocene loess. The vegetation of this collecting area is quite rich. Mohlenbrock (1954) divides Giant City State Park into nine plant communities. The general area in which we collected would be described best as within the mesic floodplain plant community of the lowlands and talus slopes bordering the lowland. The dominant trees are sugar maple (*Acer saccharum* Marsh.) and American elm (*Ulmus americana* L.). Sour gum (*Nyssa sylvatica* Marsh.) and sugar maple are the dominants on the talus slopes. The shrub layer is composed mostly of spice bush (*Lindera benzoin* (L.) Blume), American bladdernut (*Staphylea trifolia* L.), and running strawberry bush (*Euonymus obovatus* Nutt.).

The Pine Hills area is in the northwest section of Union County. This lowland area borders the road next to the bluffs at the northern limits of LaRue Swamp. The periphery of the swamp is an excellent source for mushrooms.

The Midland Hills collecting area is approximately six miles south of Carbondale near Highway 51 in Jackson County. The topography and vegetation are similar to that of certain areas of Giant City State Park.

Acknowledgments

The authors wish to acknowledge their indebtedness to Dr. D. P. Rogers, Department of Botany, University of Illinois, and E. C. Carter, Illinois Natural History Survey, for help with this problem, and to George W. Folkerts who aided us in collecting the specimens.

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Manuscript received May 10, 1963.

A CONTINUOUS-DRIP METHOD FOR THE CULTURING OF ALGAE

F. B. KULFINSKI, A. J. PAPPELIS, AND H. L. MONOSON
Illinois Wesleyan University, Southern Illinois University and University of Illinois.

A branching filamentous Chaetophoracean alga, *Chlorotylium cataractarum* Kutz., was collected from Lake Okoboji, Iowa, by the senior author and cultured in a mixture of "Chu number 10" solution (Chu, 1942) and dilute soil water medium (Bold, 1942) for several generations. Filaments of the alga adhered to solid objects in the medium. Zoospores were produced only in fresh medium. It was not possible to observe zoospores in formation, zoospore release, or filament development using standard microbiological techniques, such as hanging drop cultures.

Sterile microscope slides were suspended in newly inoculated culture medium and filaments of the alga developed on the surfaces. A special unit was designed to protect the microscope stage from water while permitting microscopic observation of the development of algal structures over a long period of time. The unit was constructed by placing a three-by five-inch lantern slide on a five-by seven-inch sheet of aluminum foil in which a hole, about one-inch square, had been cut from the central region. The margin of the foil was folded upward to form a ridge around the slide and the space between the ridge and the glass was sealed with petroleum-gel. A microscope slide covered with the alga was taken from the culture medium. One surface was wiped clean and the slide was placed on the glass surface of the water-proof unit so that the algal structures on the upper surface could be viewed. The unit and slide together were placed on the microscope stage so that the light would pass through the hole in the aluminum foil and illuminate the alga. The water-proof unit and microscope slide were held in place with rubber bands. The microscope stage was tilted slightly and a small aluminum foil trough was inserted under a lower corner of the water proof unit in such a way as to permit the nutrient solution to run off into a beaker. A separatory funnel containing sterile nutrient solution was placed above the stage so that a drop of the solution would fall on the surface of the microscope slide every six to ten seconds. This method provided light and nutrients and prevented desiccation. The nutrient solutions were collected and recycled through the separatory funnel for short-term studies. During extended studies new sterile medium was substituted every eight hours.

The method was used by Monoson (1960) to study, measure, draw, and photograph various stages of the life cycle of *Chlorotylium cataractarum*,

including zoospore production, release and morphology: development of filaments from zoospores: and development of colonies of filaments.

This method may be applied to studies of the influence of various physiological factors such as light, nutrients, and hormones, on morphogenesis and reproduction.

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THE FORERUNNERS OF THE ILLINOIS STATE ACADEMY OF SCIENCE

WALTER B. HENDRICKSON, *Professor of History*
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Cyrus Thomas and the Beginnings of the Illinois Natural History Society—1857

In 1957 the Illinois State Academy of Science celebrated its fiftieth anniversary. That year also marked the one-hundredth anniversary of the Illinois Natural History Society, the first voluntary organization for the advancement of science to be founded in Illinois. The suggestion that such an organization be started was made in a letter from Cyrus Thomas of Carbondale to Charles E. Hovey, editor of *The Illinois Teacher*. Hovey read the letter at the Decatur meeting of the State Teachers Association in December, 1857. (1)

Cyrus Thomas may well be called the father of organized science in Illinois. He was, in 1857, a lawyer in Jackson County, and his avocation was the study of natural history, especially entomology. Born in Tennessee in 1825, Thomas attended the village school and the small academy in Jonesboro. Interested in natural history as he was, he planned to become a doctor, as were so many of the scientists of the period. The necessity of earning his living prevented him from attending medical college; instead he taught school while he prepared himself to be a lawyer. But so expert did he become as an entomologist that he later was appointed State Entomologist and Professor of Natural Science at Southern Illinois Normal University. He later turned to the study of anthropology and demonstrated that the mound builders of the Middle West were not a vanished race, but Indians in an earlier phase of their culture. In this work he was closely associated with John Wesley Powell in the Bureau of Ethnology in Washington. (2)

In his letter to Hovey, Thomas proposed that an "Illinois Natural History Society" be established for the purpose of "investigating and studying" the "Flora, Fauna, Geology and Mineralogy of Illinois." The Society was also to publish the results of its investigations and studies, and to establish a museum. The Illinois State Normal University, or the Normal School as it was commonly called, had been founded in 1857. Thomas said that it should be the headquarters of the Natural History Society, and that the museum and library should be located there. Thomas envisioned the Society as a strong educational force, and proposed that the Society museum send "suites" of specimens to all the colleges and universities in the state. The legislature was to be asked to order the deposit in the Society museum of geological specimens collected by Joseph G. Norwood, just dismissed as State Geologist. The Society was to meet an-

nually at the Normal School and the members were to make collections and send them to the museum. Members were also to keep a record of their natural history observations and report them to the Society. The Teachers Association voted to issue a call for an organizational meeting to found such a natural history society as Thomas proposed. (3)

Background Forces in the Founding of the Illinois Natural History Society—1857

In proposing the organization of a state natural history society, Cyrus Thomas was in tune with the times. An interest in natural history was in the air in Illinois in the 1850's, as it was throughout the United States. In many states there was an urge to develop natural resources, and the Illinois legislature had given voice to this urge when it had established the geological survey in 1851. (4) At the same time there was much interest in improving agriculture and it was believed that a knowledge of natural science would aid farmers. The Horticultural and Agricultural Societies of Illinois were founded in the 1850's. The suggestion that the Illinois Natural History Society be associated with the new Normal School was tied in with agricultural education. An article in *The Prairie Farmer* pointed out that the farmers had backed the founding of the Normal School by the state legislature in 1857 because the teaching of agriculture would be a part of the curriculum. And, it was commonly accepted that the teaching of scientific agriculture must be soundly based on a knowledge of botany, zoology, and mineralogy. In fact, the legislature prescribed that these subjects be taught at the Normal School.

Agricultural advocates expected that the Normal School would train teachers in the natural sciences so that they could go out and teach children the fundamentals necessary to further education in agriculture, either in school or informally through books and journals, and in meetings of county and state societies. (5) An anonymous writer calling himself "An Old Agricultural Editor," wrote in *The Prairie Farmer* that the Normal School was founded for farmers, and "was thrown to us like a bone to a dog, because we had been growling for an 'Industrial University'." (6) The Industrial University was a type of institution for teaching mechanical, engineering and agricultural subjects, and the state legislatures and the national Congress were being urged to found them. Among the leading advocates of the idea was Jonathan B. Turner of Jacksonville. In 1862 Congress did pass the Morrill Act providing for the land grant colleges, which were to be much like the industrial university advocated by Turner. In 1867 Illinois established her institution at Urbana-Champaign.

There were other evidences of an interest in natural science. The Chicago Academy of Sciences had been founded in 1856 through the leadership of young Robert Kennicott, an enthusiastic collector and student of Illinois wild life. (7) Just across the Mississippi, Dr. George Engelmann, a well-known botanist, had been the mainspring in organizing

the Academy of Science of St. Louis in the same year. (8)

Educators were also concerned with natural science because many of them believed that it should be a part of the school curriculum, not so much for practical purposes, although these would not be neglected, but that an acquaintance with the world of nature would arouse a feeling of wonder and respect for God the Creator. For example, the Illinois Teachers Association at its Decatur meeting in 1857 had as its principal speaker, Professor Edward L. Youmans, a popular lecturer and publicist for science, whose subject was "The Chemistry of the Sunbeam." The editor of *The Illinois Teacher* commented that his speech was "the grandest exhibition of the eternal harmonies that pervade and link together in indissoluble unity, the most familiar phenomena of nature with the most stupendous displays of the Divine Power and Glory . . . and contributed much toward leading the Association to the earnest consideration of the subject of natural science." (9) Even such a practical man as Cyrus Thomas held that one of the main reasons for studying natural history was that, through it, one could understand the "power and wisdom of the Creator," and that eventually one could "comprehend God's design for the cosmos."(10)

The Organizational Meeting of the Illinois Natural History Society—1858

It was in response to all of these influences that the Illinois Natural History Society was organized at Bloomington in the rooms of Illinois State Normal University in June, 1858. Jonathan B. Turner was elected chairman. Turner was a former teacher at Illinois College, interested in horticulture. He was an advocate of industrial and agricultural education and, therefore, was a supporter of the Normal School. He combined in himself all the ingredients that went into the making of the Society. (11) With Turner in the chair, President Hovey of Illinois State Normal University stated the reasons for calling the meeting, and read Thomas' letter. (President Hovey had been the editor of *The Illinois Teacher* until he was appointed to head the Normal School.) A few other persons spoke, making it clear that the purposes of the proposed organization would be "to concentrate and enlarge our researches in the study of the natural history of the state," and to found a museum at the Normal School. (12) Chairman Turner appointed a constitution drafting committee of Charles D. Wilber, a teacher at Normal; Daniel Wilkins, head of the Female Institute of Bloomington and a member of the Board of Education, the governing body of Normal University; (13) Dr. Frederick Brendel, a German 48er with a European education in medicine and the natural sciences, whose specialty was botany; (14) and Charles A. Bragdon, associate editor and publisher of *The Prairie Farmer.*

The constitution reported by this committee was short and simple, providing for president, nine vice-presidents (one from each Congressional district, a device adopted from the Horticultural and Agricultural

Societies), secretary, treasurer, and general agent (an office found in the Teachers Association). The duty of the latter, as stated in the constitution, was "to visit the different portions of this and other states, make collections of specimens, attend to exchanges with various societies, establish a system of cooperation and labor to incite a general interest in the study of Natural History." The specimens thus collected were to be labeled and deposited in the museum at Normal University. Although nothing was said about it in the constitution, Wilber's salary was paid by Normal University, and his traveling expenses were covered by free transportation on the railroads. Any person might become a member of the Society if he had the favorable vote of a majority of the members, and if he paid one dollar as an entrance fee. Unaccountably no annual dues were provided for. (15)

On the recommendation of a nominating committee, the following officers were elected: Jonathan B. Turner, president; John A. Kennicott, Cook County, a farmer and a horticulturist active in state organizations and a frequent contributor to periodicals; A. R. Whitney, Lee County; Dr. S. S. Condon, Union County; Dr. Frederick Brendel, Peoria County; J. H. McChesney, geologist on the state geological survey; Dr. Bird, Kendall County; Dr. Samuel Adams, Professor of Chemistry, Geology, and Mineralogy at Illinois College, vice-presidents (only seven of the nine provided for in the constitution were elected); Dr. E. R. Roe, McLean County, physician, lecturer at Normal University on anatomy and physiology, and writer on natural history and educational subjects, treasurer; Charles E. Hovey, secretary; and Charles D. Wilber, general agent. (16)

Some supporters of the Society were not able to be present, but they wrote letters which gave information about what was expected of the Society. Dr. George Vasey (17) of McHenry County, botanist, urged that the Society prepare and distribute printed instructions for collecting and preserving plants, and for making reports to the Society. He stated that, if there were many people who knew how to gather information, soon there would be a great body of it available on the plants of Illinois. He went on to say that the Society might do something about producing an elementary botany book for the schools that would be based on the plants of the Middle West rather than upon those of the East, as were the books by Asa Gray and others. (18) From John Kennicott came an endorsement of the idea that the Society establish a museum from which sets of natural history objects could be sent to schools. He said, "The study of nature, of natural science in some shape, is the beginning and end of all practical education, and is intimately connected with every useful art and profession followed by man." (19) Cyrus Thomas wrote that he and his friends in Jackson County were collecting plants, and he hoped that the Society's museum at Normal would serve as a center for the exchange of specimens among people in various parts of the state. (20)

Addresses and Papers Delivered at the First Meeting—1858

As a climax to the first meeting of the Illinois Natural History Society, President Turner addressed the members, interested students, and townspeople, who were informed of the address by means of a printed handbill passed around to the houses in Bloomington. (21) Turner's topic was "Microscopic Insects," (22) and he spoke not only from the standpoint of an educator, but from that of the farmer and horticulturist, saying that insects, fungi, and plant diseases were a threat to the nation because they destroyed food and other products of the soil that were needed by the nation for its continuing growth and prosperity. He went on to point out that scientific knowledge was needed to meet this threat, declaring that there was a great opportunity for young men in the West who would study science, especially entomology, since "we need a score of the best minds of the country [state] under some central head, like this society, or the Normal University, provided with the best microscopes and other needed apparatus for collecting and examining a cabinet and specimens; and the whole country [state] marshalled under them. . . ." (23) Turner's address showed that he was up with the times, and that he was closely associated with the drive of horticulturists and farmers for state support for an entomologist such as was already being given in Eastern states. (24)

It is clear from Turner's speech, and from the comments of other members, that the twin scientific aims of the Society were to broaden and "liberalize" education and to be economically useful. Even the first object had the ulterior intent of arousing an appreciation of science as something that was useful. As Turner said, "We need not simply to name the beasts, but also to rule over them as did our great father Adam; and also all forms of matter." But he recognized that this could not be attained "until we know minutely their history, habits, and relations to other things and beings." (25) There was, of course, no fundamental incompatibility between the two purposes, and both were served by the Society. When the Illinois Natural History Society finally went out of existence it was succeeded by the Illinois State Natural History Museum and the Illinois State Laboratory of Natural History, the former to carry on science education, the latter to make science economically useful.

At this first meeting in 1858, the Society listened to two scientific papers, the first by Dr. Frederick Brendel, and the second by Charles D. Wilber. Wilber's paper, "The Corals of Iowa," was not printed, but Brendel's remarks, "Forests and Forest Trees," were given in full. (26) The Peoria physician and botanist first noted how, throughout history, forests had been important in the economic life of the people of Europe and Asia, and called attention to the intimate connection between vegetation, soil and climate. This was not an original idea, and he carefully cited articles in current literature to illustrate his point. He then turned to the trees of Illinois, pointing out that the forested area

was the southern one-third of the state and in the river bottoms of the northern prairie region, that most of the trees were deciduous, and the major part of these were the types that grow in river bottoms—sycamores, maples, oaks, and cottonwoods. In the whole state twenty-five families and forty-three genera were represented. Brendel soon moved away from this broad physiographical view of the Illinois forests, and took up the matter of classification and determination of species. The major part of his paper, therefore, was taxonomic, as were so many of the papers of American scientists of the time. While Brendel's paper and those of his fellows may be criticized for being dull and pedantic, yet, as Jonathan B. Turner said, collection, identification and classification were basic for any further scientific work. Although Brendel was drawn to the study of the ecology of forest trees (ecology was a term that would not be invented for several decades), he recognized the importance of taxonomy, and he was critical of much of the early identification and classification of American flora and silva done by Europeans, or in some cases by Americans, who worked in study and laboratory from dried specimens sent to them by collectors. He contended that only by associating the plant or tree with its habitat could a satisfactory classification be made. To disregard, or to be ignorant of, habitat details caused the naming of far more species than actually existed, and brought consequent confusion into botanical studies. Brendel was thus in the forefront of botanical scientists, because the great botanists of the period such as Asa Gray and George Engelmann went into the field as often as they could, and always insisted that their collectors submit habitat information with specimens. (27) To his paper, Brendel appended a check list of Illinois trees based on his own observations. (28)

Charles D. Wilber and the Early Activities of the Illinois Natural History Society—1858-1861

While the Illinois Natural History Society was in existence from 1858 to 1871, the years of its greatest activity were 1858 to 1861. It continued to meet during the Civil War, but not much was done. Efforts to revive it after the war met with little success. In one sense the parent devoured the child, because the museum at Normal became more important than the Society. Eventually the Society was dissolved and the Museum turned over to the state. The history of the Society, therefore, divides itself into two parts: before and after the Civil War. During the first part, cooperation and mutual assistance between the Society and Normal University prevailed. Annual meetings were held at the University in June during Commencement Week, or as it was called, Anniversary Week. In between meetings the activities of the Society were directed by the General Agent, Charles D. Wilber, Professor of Geology at Normal, and largely responsible for what success the Society had. Immediately after his appointment in 1858, he went on a tour of the state, securing from the railroads free transportation for himself and for the specimens he gath-

ered from collectors such as Brendel and Thomas. Since Wilber's salary was paid by Normal University, he was responsible to Charles E. Hovey, the president, and in a detailed report to him Wilber described his work. (29) His principal concern was to get the natural history survey of the state under way, and to accumulate material for the museum. He issued a circular giving directions for the study of natural history, and it was printed in both *The Illinois Teacher* (30) and *The Prairie Farmer*. (31). In it he said that since the object of the survey was "to make the study of Natural History accessible to everyone," it should "enlist the energies of every intelligent and enterprising teacher." He then gave detailed instructions for collecting and preserving natural history objects, adapted from a circular prepared by Robert E. Kennicott.

Following the suggestions of Thomas and other members, Wilber made contacts with a number of men who were already carrying on some kind of natural history study or making collections. Among them was Dr. George Vasey of McHenry County, a young man who was born in England, came to the United States as a child, and grew up in New York, where his enthusiasm and talent for natural history attracted the attention of Asa Gray and John Torrey. He earned his M.D. degree and came west to McHenry County to practice. He did much botanizing, being especially attracted by the prairie grasses. His personal collection of these had importance to botanists because it contained so many specimens from the virgin prairie. He later became a professional botanist, being employed by the United States Department of Agriculture. He also arranged the large herbarium of the Smithsonian Institution so that it could be used by scientists. (32) From Vasey, Wilber obtained over a thousand specimens for the Society's museum. (33)

Robert Kennicott was another young man who assisted Wilber. Kennicott, the son of Dr. John Kennicott, the horticulturist and farmer of Northfield in Cook County, was born in New Orleans in 1835, but was brought to Illinois as a baby. Under his father's tutelage, he learned a great deal about the outdoors, and became an avid natural history collector. So much had he learned about the wild-life of the state that he was named to make a natural history survey of the just completed line of the Illinois Central Railroad. His success brought him to the attention of men in Chicago, and he inspired them to contribute money for the museum of the young Academy of Sciences. His accurate work attracted the interest of Spencer F. Baird, the Assistant Secretary of the Smithsonian Institution, and Kennicott was invited to come to Washington to go over the collections of the Smithsonian. Young Kennicott was at his best in the field. He made important collecting trips to Minnesota and to Canada as far north as the Yukon River. His knowledge of this country brought him a post on the party sent out by the Western Union Telegraph Company to survey a projected (but never built) line from the Pacific coast to Alaska, across Bering Strait to Siberia, and then to

western Europe. While on this job, Kennicott died in Alaska at the age of thirty-one. (34)

Others who collected material and contributed it to the Society museum were Dr. Brendel, Cyrus Thomas, Amos Worthen, the state geologist, and J. H. McChesney, his assistant. Others whose names only are known were E. S. Bond, Henry County; and Richard H. Holder, McLean County, both ornithological collectors; Samuel Bartley, a friend of Cyrus Thomas in Jackson County; Dr. E. R. Roe, McLean County; Judge Snyder, Belleville; Dr. Mead, Hancock County; and R. G. Oaks and Professor Sheldon of Kane County. (35)

Wilber also encouraged the founding of county natural history societies, but with what success is not known.

The Illinois Natural History Society Museum at Illinois State Normal University— 1858-1862

One result of Wilber's years in the field was that at the meeting of the Natural History Society in 1860 "commissions" in the various branches of natural history were created so that men of like interests in different parts of the state might work together. (36) Wilber also opened negotiations for museum material with the geological surveys of the surrounding states, and contacted foreign missionaries and other persons in Europe and Asia. A start on a science reference library was also made. (37)

The upshot of all this volunteer work was the accumulation of 60,000 individual specimens by 1862, which, if they had had to be paid for, Wilber estimated would have cost $23,000. While the collection was being made, Normal University completed its main building in which two large halls with a combined area of 100 x 33 feet were set aside for the museum. The arrangement of the cases in this room was carefully planned by Richard H. Holder, the ornithologist and taxidermist of Bloomington, after he visited museums in Philadelphia, Boston, and Salem. At the front of the room were twelve large cases of "pure French glass" each four by eight feet and ten feet tall, in which Holder's and Bond's bird collections were arranged by families, each specimen standing stiffly on its wooden perch. Opposite the bird cases were those containing fossils from coal, some of them in quite large pieces. Here also were the fossils from the rock strata of the Carboniferous period. Back of these two sections were floor cases containing drawers for insects and plants. Along the walls were cases of fossils — shells, corals, sponges, etc., — and minerals, ores, and rocks, the former arranged by geological epochs and the latter according to the locality in which they were found. Also displayed on shelves were glass jars containing specimens of reptiles, fishes, and shell-fish preserved in alcohol. On the wall above the cases of geological specimens were the first four of what was to be a series of paintings illustrating the great epochs of geologic time. The artist was J. E. Bryant of Bloomington. (38)

The purpose of the museum, as Wilber saw it, was "simply to pre-

sent a type of all the species of [sic] existence in the various kingdoms of nature, ancient and modern, arranged according to the type or affinity of each group. It is a *human* attempt to represent, as far as possible, the *divine* idea of creation, by a real panorama of objects.'' (39) Wilber was an advocate of what was then the ''modern'' educational method of teaching by seeing and doing rather than by rote from textbooks, and he declared, ''by the judicious use of this great collection, under proper regulations, students who attend this Institution [Normal University] from all parts of the State, can obtain a general survey of our material resources, and will learn one important fact at least, that our home facilities for education, the new, or reformed method of object lessons are unequalled.'' (40) From this array of the ''medals of creation'' the student would learn a pre-Darwinian view of nature: that God the Creator had successively brought into existence new forms of life to fit new conditions, each form more advanced than the preceding one, ''until the culmination of the grand plan, in the advent of the human race.'' As the student viewed this progression upward, Wilber said, ''ask him . . . if the works of God do not impress him with the higher conceptions of the wisdom, beneficence and accompanying presence of the great Creator.'' (41)

The value of the museum was so evident to Wilber that any persons who questioned it, he said, ''belonged to a past epoch, and may be termed the fossils of society, who are labeled and laid away.'' (42)

But there *was* questioning of Wilber and the Natural History Society museum. It seems clear that he was so absorbed in the work of collecting and displaying natural history objects to create a museum for teaching purposes in what he considered the broad sense of making the student aware of God and His creation that the utilitarian purposes of the Society and the museum were neglected. When, for example, Wilber reported that the museum would display objects from Europe and other parts of the world, *The Prairie Farmer* said bluntly that it was more important that the museum have plants of Illinois than shells from the Sandwich Islands, because farmers would not benefit from such strange things. (43)

Although further additions were made to the museum, it did not expand greatly during the Civil War years. As Wilber reported to President Hovey:

> Hard as the work was, our progress was remarkable until the war broke out, which is death to Science and Art. But even amidst the smoke and carnage of the past eighteen months, we have *added many thousand* specimens to the collection; but the grand work must stop now, for a while at least, there are few to help—nearly every naturalist is in the army—there is no money, and the future is unpropitious indeed. (44)

Activities of the Illinois Natural History Society—1859-1862

While Wilber and his volunteer collectors built the museum, the Society itself continued to meet annually in Bloomington. In 1859 the constitution was revised by dropping the initiation fee and making annual dues two dollars. The office of General Agent was abolished, and the

new one of Superintendent was created for Wilber. The museum was put in charge of a curator, and Cyrus Thomas was named for the post, but since he lived at such a distance, the actual direction of the museum remained in Wilber's hands. The constitution also provided for an executive committee of five members, a necessity for a state-wide organization that had only one meeting a year. Jonathan Turner was re-elected president, although he was not present at the meeting, and nine vice-presidents and other officers were named: Dr. Edmund Andrews, Cook County, a member of the Chicago Academy of Sciences; A. M. Gow, Lee County; Frederick Brendel, Peoria County; J. H. McChesney, Sangamon County; B. G. Roots, Perry County; Ben Wiley, Union County; William Le Baron, Kane County; M. L. Dunlap, Champaign County; and Dr. E. R. Roe, McLean County. The secretary was S. B. Mead of Hancock County; treasurer, Dr. E. R. Roe; curator, Cyrus Thomas; superintendent, Charles D. Wilber; executive committee, Ira Moore, C. D. Wilber, Charles D. Bragdon, Dr. George Vasey, and Cyrus Thomas. (45)

Of the men assuming leadership for the first time, Andrews was a physician of Chicago, much interested in natural history, Dunlap was an orchardist, Root was an educator, Le Baron was a physician in Geneva and a student of entomology who later became State Entomologist, Moore was a teacher at the Normal University, (46) and nothing is known about Mead.

The Society agreed to call a meeting of scientists from the states bordering on Illinois so that there might be cooperation in surveying the natural history of the whole area, but there is no record that the meeting ever took place. The Society authorized the superintendent to arrange for an exhibit from the museum at the forthcoming state fair at Freeport, a task which was successfully accomplished by Wilber. The Society also decided that a catalog of plants and animals of Illinois be published, and these appeared in the transactions of the Society as noted below. The superintendent was instructed to work out a means of distributing natural history collections to the schools of the state. (47)

At the time of the next meeting in 1860, Wilber, just given the new title of Secretary, reported that there were 140 dues-paying members, although only thirty were actively engaged in the study of natural history, and that the former gave their support because they recognized the importance of the work of the Society. It was at this meeting that the active members were assigned to "commissions" so that the work of making a natural history survey might go forward. These were the commissions and their members:

Botany: Dr. George Vasey, Ringwood, McHenry County; E. Hall, Athens, Menard County; M. S. Bebb, Springfield; Dr. Frederick Brendel, Peoria; Dr. S. B. Mead, Augusta.

Geology and Mineralogy: C. D. Wilber, Bloomington; J. W. Foster, Chicago; Rev. O. D. W. White, Mt. Carroll; Dr. Oliver Everett, Dixon.

Paleontology: A. H. Worthen, Springfield; J. E. Reynolds, Springfield; Dr. M. Davis, Oswego, Kendall County; James Shaw, Mt. Carroll.

Conchology: J. W. Powell, Wheaton; Dr. Lucius Clark, Rockford; M. S. Bebb, Springfield; Dr. E. R. Roe, Bloomington; E. Hall, Athens.

Entomology: B. D. Walsh, Rock Island; Cyrus Thomas, Murphysboro; Dr. J. A. Sewall, Bloomington; Dr. William Le Baron, Geneva.
Herpetology: Robert Kennicott, Northfield; U. D. Eddy, Bloomington; J. Johnson, Vienna.
Icthyology: Dr. Adams Nichols, Quincy; Dr. William H. Giddens, Hamilton; Dr. L. Watson, Quincy.
Mammalogy: William H. Gearhard, Murphysboro; Cyrus Thomas, Murphysboro.
Ornithology: R. H. Holder, Bloomington; Dr. J. W. Velie, Rock Island; A. M. Gow, Dixon.
Meteorolgy: E. Hall, Athens; Dr. Samuel Willard, Bloomington; Rev. W. W. Harsha, Dixon; James Shaw, Mt. Carroll.
Drawing and Painting: J. E. Bryant, Bloomington. (48)

This is probably a rather complete list of the active naturalists in Illinois in the middle of the nineteenth century. It has not been possible to identify each person, but the following men played a greater or lesser part either because of their work in the Natural History Society, the State Geological Survey, or because of their later work in their chosen fields: Vasey, Brendel, Wilber, Foster, Worthen, Powell, Roe, Walsh, Thomas, Sewall, Le Baron, Kennicott, Holder, Velie, and Gow.

Papers and Addresses Read to the Illinois Natural History Society—1860

As noted above, the Natural History Society's activities slowed down during the Civil War, and there is no official record after Wilber's report of 1862. In 1861 the Society received a charter from the legislature, (49) and Wilber continued to direct the museum until 1864. (50)

The practice of reading scientific papers established at the first meeting was continued. In 1859 papers were presented by Cyrus Thomas, "The Study of Natural History"; Frederick Brendel, "On Meteorology in Connection with Botanical Investigations"; George Vasey, "Mosses of Illinois"; Cyrus Thomas, "Orthoptera of Illinois"; and E. R. Roe, "Notes on the Great Drouth in '53 and '54." (51)

Thomas' first paper illustrated clearly his familiarity with the orthodox natural science theories and beliefs of the time. In the spirit of the German idealistic philosophy of nature (52) Thomas saw natural history, not as isolated facts and phenomena,

> but most admirably linked together and interwoven around the great central stem—Design—from which every root sends forth its culms. Consequently the more and more of this knowledge we acquire, the more we know of God's infinite power and wisdom; and the nearer we are approaching His eternal throne. And were it not that this wisdom is as limitless as space itself, we might hope that the great I AM has prepared inexhaustible fields of knowledge for us to explore that even eternity shall leave untouched.
>
> I believe the mind of man is capable of continued expansion, and that the day will come on this earth in which a single mind will be capable of grasping the entire "Cosmos", of which the lamented Humboldt could discern the shadowy outlines, but which he in vain attempted to point out to others. (53)

Thomas believed that science should be taught at all levels in the schools because it would discipline and enlarge the mind, prepare the student for future prosecution of the subject, show how the most practical use can be made of the knowledge gained, and instill in the student a love of science. In teaching Thomas advocated what was usual in his day, a progression in an orderly manner through the various branches of natural science, beginning with botany,

and using the natural system of classification as an outline. Thomas also made the point that it was not enough for students to read books, but that they must learn from the objects themselves in the field and in the museum. (54) Thomas was not an innovator, but he was well-informed about current science and science education.

The paper prepared by Dr. Brendel was read by Wilber. It presented the results of Brendel's attempt to determine exactly how high the temperature of the atmosphere had to be to ripen seeds and bring plants to flower. The paper was concerned with methods of making meteorological observations to provide accurate time-interval readings, but of course his methods have been outdated because of the introduction of sensitive clock controlled recording devices. (55) It was not that Brendel's techniques or the results of his research were themselves important, but that the paper indicated that Brendel, with his European education and his contacts with other scientists outside of Illinois, had moved beyond a preoccupation with taxonomy to the study of plant physiology, and so was working in the direction already taken by the leaders of botanical research in eastern United States and in Europe.

In contrast, the papers by Vasey and Thomas were simply annotated lists of species of plants that had been collected and presented to the Society's museum.

Dr. Roe's paper was an interesting exercise in drawing conclusions from observed facts. Roe noticed that certain mollusks characteristic of rivers were found in prairie ponds. He concluded that the ponds had remained when a river, at some remote time, had disappeared during a drought. And now in an extreme dry spell the mollusks had all died when the ponds dried up. But Roe held that the mollusks had been in the ponds for a very long time because he found their shells as deep as five feet in the soil below the bottom of the dried up ponds. It was his conclusion that the "drouth of 1853-54 was greater than had ever occurred since the disappearance of the river that had supplied the ponds." (56)

Other papers were presented at the 1860 meeting. These may be divided into three categories: (1) Those that were taxonomic or descriptive: R. H. Holder, "Birds of Illinois, a Catalogue"; Oliver Everett, "Geological Section of Rock River"; Cyrus Thomas, "Insects of Illinois, with Catalogue of Coleoptera", and "Mammals of Illinois"; George Vasey, "Additions to the Flora of Illinois"; Benjamin D. Walsh, "Insects Injurious to Vegetation in Illinois." (2) Those concerned with some extraordinary natural phenomena: James Shaw, "The Great Tornado of 1860"; C. D. Wilber, "The Mastodon Giganteas [sic]"; Frederick Brendel, "The Water Lily." (3) Those that were on science education: Jonathan B. Turner, "Mind, Force and Matter"; A. M. Gow, "Natural History in Schools"; R. H. Holder, "Taxidermy"; J. H. Blodgett, "Object Lessons"; Cyrus Thomas, "Plan for a Natural History Survey"; C. D. Wilber, "Museum of the Illinois State Natural History Society." (57)

President Turner's address was

essentially inspirational and philosophical and he urged that the members of the Society, in the spirit of Baconian scientific method, keep open minds, gather information, classify it, and draw conclusions. Turner saw God as the Creator, but held that the creative process was a continuing one, and that man, as the highest expression of God's creativity, had the "power" to understand the "force" that created all "matter." (58) Gow's paper on natural history in the schools had been read first at a meeting of the Illinois Teachers Association, and in it he pointed out much the same things that Thomas and other writers did, that the child not only gained much useful information about nature, but that he developed his ability to observe accurately and draw conclusions. (59) In "Object Lessons", Blodgett expanded on the idea that had been first conceived by such European educators as Pestalozzi and Froebel, and widely accepted in the United States, that it was much better to teach from the object itself rather than from a textbook account. (60) Holder's paper on taxidermy was an illustrated description of the proper way to skin and stuff birds for display, (61) and Thomas' paper brought together ideas that had been scattered through his letters and other communications to the Society on the matter of conducting the natural history survey in Illinois. (62) Wilber's paper on the museum contained a description of the physical arrangements at Normal, and gave some information on the objectives he hoped would be realized to make the museum an educational medium. (63)

The group of papers on plants and animals in Illinois constituted the results of the attempt to survey the wild-life of Illinois, and to provide the information which it was believed would be useful to farmers.

The papers on natural phenomena were not the result of original research, but were concerned with matters of popular scientific interest. Wilber's paper went into detail on how and why the bones of an elephant-like animal, a creature associated with the tropical jungles, were found in Illinois. (64) The water lily, a curiosity among plants, was pictured by Brendel in a careful drawing, and the peculiar way in which it grew was described. (65) While there was nothing new in either paper, they were carefully written in proper scientific style. Also of much popular interest was Shaw's account of the great tornado of 1860 which had swept across northern Illinois and up into Michigan, doing much damage to property. The author not only described the effects of the storm, but took up the question of whether electricity in the atmosphere caused the storm, or whether the storm caused the electricity. Shaw reviewed the literature on storms from Franklin to Joseph Henry and James P. Espy, agreeing with the latter that electricity was the result of the storm. (66)

On the whole it was a group of high quality papers, demonstrating that Illinois scientists and teachers were industrious, careful observers, and abreast of the best thinking in their fields.

With the cessation of activity by the Natural History Society during the Civil War there was no further

publication, the natural history survey was dropped, and interest in the museum at Normal University declined.

John Wesley Powell and the End of the Illinois Natural History Society—1866-1871

But when the war ended scientific activity was resumed under the leadership of a new personality—John Wesley Powell. This man, destined for a distinguished career as explorer, geologist, and ethnologist, was born in New York in 1834, and was educated at Oberlin College in Ohio and at Illinois and Wheaton Colleges in Illinois. It was while he was a student at Wheaton that he began his study of the natural history of Illinois during summer trips by canoe on the Illinois, Ohio and Mississippi Rivers. (67) In 1859 he had contributed to the Society's natural history survey, and in 1860 he was appointed to the commission on conchology.

Powell saw service in the Civil War as a member of the Thirty-Third Volunteer Regiment, known as the Schoolmaster Regiment, and at the end of the conflict he came to Illinois Wesleyan University in Bloomington as Professor of Natural Science. He immediately became associated with the Natural History Society and, with other enthusiasts in Bloomington, organized a local chapter. (68) He also visited the Society's museum at Normal University, where he found things in a confused and disorganized state. With the departure of Wilber, there was no one responsible for maintaining the museum. In spite of the professed intention of the University to teach science, and the belief that the museum would make this possible, science courses had no secure or important place in the curriculum. Very few students took any work at all.

As President David Felmley said in reviewing the course of study, "It is a question whether the faculty or board [Board of Education, the governing body of the University] were fully persuaded of the real value of the studies. They were postponed to the latter part of the course. Chemistry preceded the others in the belief that it would solve the problems of animal and vegetable physiology. Zoology was put at the end of the senior year; later it was an elective; some years it was not taught at all." (69) The deplorable lack of instruction in science is even more clearly recognized when it is realized that only a small number of students ever became seniors. In 1862, for example, out of 506 students in attendance since the founding of the school, only twenty-six completed the three-year course and received diplomas, and most students attended for only one year. (70)

The neglect of the museum alarmed Powell and his associates in Bloomington. At the meeting of the Illinois Natural History Society in June 1866, Powell proposed that the Society consult with the Board of Education about obtaining funds for the support of the museum, and until further arrangements could be made, Dr. Joseph A. Sewall, Professor of Natural Science at Normal, would have charge of it. Sewall, who had an M. D. from Harvard University and had studied science with Asa Gray and Louis Agassiz,

was appointed to the faculty in 1860. (71) Since displays had been disarranged and some things stolen, Sewall was to open the museum to the public only on Fridays, and even then all the cases were to be "firmly closed." (72) Powell and Drs. Roe, Stennet, and Parke were directed to contact the Board of Education, and Powell, acting for this committee, drew up an appeal for financial assistance to the Society for the maintenance of the museum. In it he pointed out that this aid was necessary if the Society was to carry out its aims, which he listed as (1) to promote original research in natural science, (2) to make a natural history survey of the state, (3) to supply schools and colleges with natural history specimens for teaching purposes, and (4) to build and maintain a central museum at Normal. (73)

Before continuing with Powell's career, it may be noted that, while these four aims had been the objectives of the Natural History Society from its beginning, the earlier emphasis on the importance of natural science in teaching agriculture was absent. The interest of the farmers had shifted in nine years to the implementation of the Morrill Act, which had passed Congress in 1862, and the Illinois Industrial University was opened at Urbana-Champaign in 1867. The horticulturalists who had supported the farmers in boosting the Natural History Society had now turned their attention to a drive for the establishment of the office of State Entomologist, and this, too, was done in 1867. (74) This left only the Normal University as a possible backer of the Society and Powell's appeal was based wholly on the idea that natural history was a major concern of an educational institution.

Powell explained to the Board that the objectives of the Society could not be achieved, and that the museum could not be useful to the University, unless a full-time general commissioner and curator was appointed, and he estimated that $2500 annually would be required — $1000 for museum expenses and $1500 for the salary of the curator—and that, even so, success would only be achieved if the members of the Society would continue to give of their time and talents to do the necessary field work, "prompted by their love of research and their desire to spread a knowledge of the natural sciences among the people." Powell went on to say that the necessary funds should be provided by the state legislature and that "the barest statement of the objects and requirements of the Society [was] the best argument that [could] be urged in favor of legislative aid." This was not a new venture, he said, because generally in Europe, scientific societies were given financial support by government, and in the United States there was also a precedent in the contributions made by Congress to the Smithsonian Institution. And, finally, he pointed out that "the appropriation asked for is but a trivial thing compared with the amount of labor to be done, the educational interests to be subserved, and the good to be done to the whole people of the State." (75) With full support of the members of the Board of Education, Powell went to Springfield to lobby for his proposal, and

he was successful. The legislature appropriated the $2500 for which Powell asked, and placed it in the hands of the Board of Education, giving it the authority to appoint a curator in consultation with the directors of the Natural History Society. (76) As might have been expected, Powell was immediately appointed curator by the Board of Education and the directors of the Society. (77)

From this moment the Illinois Natural History Society ceased utterly to be an effective organization for advancing scientific investigation or science education in Illinois. While the Society nominally owned the natural history objects in the museum, the cases and furnishing belonged to Normal University, and while the Society's directors were to be consulted on the appointment of a curator, the governing body of the University, since it held the purse strings, did in fact determine who that man would be and what policies and programs he would carry out in the name of the Society.

John Wesley Powell immediately used his position and his influence with the Board of Education for his own purposes, and those purposes had only slight connection with the purposes pursued by the Natural History Society since its founding—the fostering of science in Illinois. Powell's purpose was his plan for an exploring and collecting trip to the Rocky Mountains. It was not that Powell was in any way dishonest, or that he was not sincerely devoted to science, or that he did not make important contributions to science through his explorations. He was honest, he was a dedicated scientist, and his trips to the Rockies and the Colorado River region yielded valuable scientific information. But none of these had anything to do with science in Illinois. (78)

Powell, although a fine teacher in the classroom, preferred traveling and field work, the spectacular and exciting side of the life of the scientist. He was able to convince the Board of Education that Normal University would serve the interests of science in Illinois by spending $500 of the $1000 appropriated by the legislature for the museum to finance Powell's first exploring trip to the Rocky Mountain region. He also secured funds from the new Illinois Industrial University (soon to be renamed the University of Illinois) and the Chicago Academy of Sciences. The railroads promised free transportation, and the United States Army agreed to provide some equipment and supplies, as well as a military escort. The students and others who went along as naturalists or laborers paid a part of their own expenses. (79)

Powell was very successful in collecting large quantities of natural history and ethnological material, and by January, 1868, boxes and barrels of specimens cluttered the halls and rooms at Normal awaiting preparation and labeling. Powell needed this large amount of material, not only to fulfill his promises to Normal, but to his other sponsors as well. (80) When Powell himself returned to Bloomington, he hired four assistants to unpack and arrange the material, and by June, 1868, he was able to show the members of the Board of Education a large number of additions to the museum. This,

plus the considerable fame Powell won through his lectures and newspaper articles, brought the Board to agree to support a second expedition, this time to the Colorado River country, including the Grand Canyon. (81)

Once again a great amount of material was shipped back to the Society's museum and by 1870, when it was finally arranged, the museum was so overcrowded that the Board was considering a plan drawn up by Powell, Vasey, Sewall and A. H. Thompson (superintendent of schools in Bloomington and a member of one of Powell's expeditions) for a two story fireproof building.(82) But the Natural History Society itself played little part in these activities, although it did meet occasionally with Dr. George Vasey as president and Powell as secretary. (83) The future of the almost moribund Natural History Society was thoroughly canvassed at the 1869 meeting, and it was agreed that the Society should divest itself of its museum and go out of existence. (84) The matter was brought to a head in 1871 when the legislature attached to its appropriation of $2500 for the museum, the provision that the Society should transfer to the state its claim to the cases and exhibits. The transfer was authorized at a meeting of the Society held in Bloomington, June 22, 1871, and the Board took legal ownership of the museum. (85) The Illinois Natural History Society went out of existence.

In the thirteen years since its founding, and especially during the first three years, the Society had performed a most valuable service. As the pioneer effort at a voluntary association for the promotion of science education and research, it laid the foundations for the Illinois State Academy of Science, the Illinois Natural History Survey, and, to some extent, for the Illinois State Museum. It had strengthened the work of the professional, semiprofessional and amateur scientists, and had provided a center for their cooperation. (86) But it did not succeed permanently in reaching its own objectives for the following reasons: (1) the lack of money to maintain either the natural history survey or the museum, (2) the disruptive influence of the Civil War, and (3) the coming of John Wesley Powell to the curatorship of the museum, the clash of his personal interests with those of the Society, and the disregard of the latter for what he and the Board of Education considered to be more significant.

Stephen A. Forbes and the High School and College Association of Natural History—1878-1882

There was a second scientific organization that had its center at Normal University, although it was much more limited in its objectives than the Illinois Natural History Society. This was the High School and College Association of Natural History, organized in 1878 and existing until 1882. It was started by the enterprise of Stephen A. Forbes, the new curator of the natural history museum, who succeeded Powell after Sewall filled the post briefly.

Forbes was born in Illinois in 1844 and was mostly self-educated, although he spent a year or two at

Beloit Academy and at Rush Medical College in Chicago. As was true of most natural scientists, he had been interested in natural history from his boyhood, and when he left Rush without graduating, he taught school and continued to study and write about it. Forbes had a distinguished career as a scientist in the employment of the state of Illinois. Starting as the head of the museum at Normal, he became director of the State Laboratory of Natural History and State Entomologist, and continued as director of the Illinois Natural History Survey when that organization took over all state research concerned with natural history. He was Professor of Zoology at Normal, and after 1885, when the state activities in natural science were moved to Urbana, he held the same post at the University of Illinois. He earned a Ph.D. degree from Indiana University in 1884 by submitting a thesis and taking an examination. After a long and productive career, characterized by skill in administration and high scholarship, he died in 1930. (87)

The appointment of Forbes at Normal came at just the time that the legislature passed a law requiring that natural science be taught in the elementary schools, and teachers were required to demonstrate their proficiency in the subject in order to hold certificates. (88) As Forbes said, "Many of the teachers finding a difficult and unfamiliar labor precipitated upon them, having but scant facilities for preparation and little knowing how to use what they had at hand, were eager to avail themselves of all offered aid." (89) In the rush to qualify, teachers boned up on the subject from what books were at hand, regardless of their authority; examiners often no better informed than the teachers, set standards for certification. Since it was known that the museum at Normal had in the past supplied materials to teachers, there was now an increased demand for suites of rocks and minerals, herbaria, and zoological cabinets. Forbes was embarrased by these requests because he did not have enough material to pass around. The museum had never been in a position to give carefully organized teaching exhibits, although that had always been its aim. Most often it had just sent out whatever duplicates it could spare.

To remedy this situation and get enough proper material, Forbes first tried to get school authorities and teachers themselves to gather quantities of natural history objects and send them to him. He promised that he would select, arrange, and label proper teaching units and send them out to cooperating schools. Although there was only a small response to his offer, it was enough to encourage him to take another step. As he reported, "In the autumn of 1873 . . . , it was determined to attempt the organization of a new society of natural history, which would have for its leading purpose the supply of practical working collections to the schools, through the labors of the teachers themselves." (90) At the State Teachers Association meeting at Bloomington in December, 1873, Forbes met with a group and formed the School and College Association of Natural History of the State of Illinois. A constitution was

adopted, and President Richard Edwards of Normal University was elected president, and Forbes, secretary and curator. The constitution stated that the rather limited purpose of the society was that of carrying out the plan of cooperative collection of natural history teaching materials, just as Forbes had proposed. (91) For a year or two work went on, not on as large a scale as Forbes would have liked, but he thought the effort most worthwhile for those who did collect material, because they depended less on textbooks in their teaching and more on the objects themselves. The organization also provided a forum in which teachers could discuss their common problems. (92)

The State Natural History Society of Illinois — 1878-1885

Through the Association, and in other ways, enough interest in natural history was aroused for Forbes to organize, in 1875, a summer school on the pattern of the school at Penikese Island conducted by Louis Agassiz, the Harvard University naturalist and exponent of the philosophy of learning about nature in the field rather than from books. (93)

At a second summer school in 1878, the students were so enthusiastic that they founded an "Agassiz Society" and appointed a "committee of correspondence" to arouse state-wide interest. (94) The result was an organization meeting in the Springfield office of Amos H. Worthen, the State Geologist, on December 12, 1878, and a full-scale meeting at the Palmer House in Chicago on January 16, 1879, where forty persons were in attendance and fourteen more sent messages of support. Worthen was elected president and Forbes secretary; a name was selected—The State Natural History Society of Illinois—and a constitution was adopted. (95) This document was very brief, saying little about the purposes of the new organization except that "its field of observation and research shall comprise Geology, Archeology, and Biology in all its departments." An initial membership fee of three dollars, and annual dues of one dollar were to be collected. The real control of the organization was in the hands of an executive committee "who were to act on all matters referred to it by the Society." (96) By the end of 1879 there were sixty-six members, ten of whom were professional scientists—teachers in colleges and in the employment of the state. These men were J. D. Conley, Blackburn College; Thomas J. Burrill, University of Illinois; Selem H. Peabody, University of Illinois; Rev. Francis X. Shulak, St. Ignatius College; E. S. Bastin, University of Chicago; Professor J. Lindahl, Augustana College; Prof. Oliver Marcy, Northwestern University; A. H. Worthen, State Geological Survey; Cyrus Thomas, State Entomologist; and S. A. Forbes, State Laboratory of Natural History. (97)

As Forbes said, "this was the period of the return to nature in the study of science," so field trips were regular features of the semiannual meetings of the State Natural History Society. At the second meeting there was a program of papers. The first field trip was in 1879 with three groups—geological, with Worthen as

the leader; botanical, with Burrill; and zoological, with Forbes—all hiking for sixteen miles along the Illinois River from Ottawa to Peru. In other years field trips were held at Lake George in Indiana, and at Fountain Bluff and Grand Tower, Warsaw, and Peoria, on the Illinois River. Those attending were pleased with the trips, "but more for fellowship than permanent scientific value." (98) Meetings at which papers were read were held at Bloomington, Springfield, Peoria, Urbana, and Jacksonville. In 1881, at the Springfield meeting, where the sessions were held in the Supreme Court Room, a Mr. McAdams "described ancient agricultural instruments of stone from mounds in Missouri and Ohio" and exhibited "carbonized corn." The discussion which followed was "quite extended." A paper on artesian wells read at the same session was continued in the afternoon, and then Professor Burrill of the University of Illinois talked about bacteria ferments. (99)

A year later the meeting was at the University of Illinois and a number of papers were given, many of them by members of the staff of the University or of the Natural History Laboratory. None of the papers were outstanding original contributions to science, but they all indicated that that much study and thinking about the problems of natural science was going on, and that the University was the chief center of such activity in the state. Here is a list of the papers and their authors:

"Recent Microscopy," T. J. Burrill, U. of I.
"Prehistoric Remains in Southeastern Missouri," F. S. Earle, Cobden.
"The Fossil Tracks of the Connecticut Valley," Don Carlos Taft, U. of I.
"The Army Worm in 1881," F. M. Webster, Waterman.
"The Organs of the Sixth Sense of Blind Fishes," S. A. Forbes, U. of I.
"Primitive Religion in America," Mr. McAdams, Jerseyville.
"The Rock System of the Northwest," Edwin Evans, Streator.
"Sciences in the Public Schools," C. W. Rolfe, U. of I.
"The Great Cahokia Mound of Madison County," Mr. McAdams, Jerseyville.
"Some Vegetable Poisons," T. J. Burrill, U. of I.
"The First Food of the Whitefish," S. A. Forbes, U. of I.
"The Blue Process of Copying by Photography," N. C. Ricker, U. of I.
"The Life History of the Jelly Fish," James A. Armstrong, Champaign.
"The Subterranean Waters of the Northwest," Edwin Evans, Streator.
"Field Work on Parasitic Fungi," A. B. Seymour, State Laboratory of Natural History.
"Zoological Notes from a Field Book of a Naturalist," Cyrus W. Butler, State Laboratory of Natural History. (100)

From this high point at Urbana, interest in the State Natural History Society declined, and attendance at meetings fell off so that, after the Jacksonville meeting in 1885, the organization was disbanded. As Forbes pointed out, there were too few professional scientists to maintain the program of giving papers inasmuch as it had been decided not to broaden the membership to admit physical scientists, and no publication was undertaken. The Society existed almost altogether for the fellowship that came from the field trips, and the information gained from the scientific papers read by a few members. (101)

In spite of three promising attempts, the permanent organization of the scientists of Illinois had to wait until the Illinois State Academy of Science was founded in 1907, when all the objectives of the former organizations were made a part of the latter's two-fold program: the

education of school children to appreciate and understand the world of nature, and the encouragement of original research by advanced students and mature scientists.

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3 "Illinois Natural History Society: Natural History Convention," Illinois State Agricultural Society, *Transaction*, III (1859), 637-38.

4 State of Illinois, 17th General Assembly, *General Laws*, 1851, pp. 154-55; Alja R. Crook, *A History of the Illinois State Museum of Natural History* (Springfield, 1907), 7-8; George P. Merrill (ed. and comp.), *Contributions to a History of American State Geological and Natural Surveys*, Smithsonian Institution, *Bulletin 109* (Washington, 1920), 64-67; C. W. Rolfe, "Investigations Previous to the Founding of the Present State Geological Survey," *Papers Presented at the Quarter Centennial Celebration of the Illinois State Geological Survey*, Illinois State Geological Survey, *Bulletin No. 60* (Urbana, 1931), 24-25.

5 *The Prairie Farmer*, III (1859), 90.

6 *Ibid.*, II (1858), 358; Helen E. Marshall, *Grandest of Enterprises* (Normal, 1956), 1-39.

7 William K. Higley, *Historical Sketch of the Academy*, Chicago Academy of Sciences, *Special Publication No. 1* (Chicago, 1902), 5-6.

8 Henry M. Whelpley, "A Sketch of the History of the Academy," Academy of Science of St. Louis, *Transactions*, XVI (1906), xxiii-xxiv; Ralph S. Bates, *Scientific Societies in the United States*, 2nd edition (New York, 1958), 48-52.

9 Illinois State Teachers Association, "Proceedings," *loc. cit.*, IV (1858), 2.

10 "The Study of Natural History, Illinois State Natural History Society, Proceedings, 1859," Illinois State Agricultural Society, *Transactions*, III (1859), 665.

11 Marshall, *Grandest of Enterprises*, 6-26; Mary T. Carriel, *The Life of Jonathan Baldwin Turner* (Jacksonville, 1911), 258-59.

12 Bloomington *Daily Pantagraph*, July 1, 1858.

13 It has been difficult to find biographical information about many of the men connected with the Natural History Society; not even first names have been determined in many cases. Any substantial biographical source will be cited in the footnotes, but bits of information found incidentally in other places will not be documented.

14 Virginius H. Chase, "Frederick Brendel, the Pioneer Botanist of Peoria," Illinois State Academy of Science, *Transactions*, XXIV (1931), 73-79.

15 "Illinois Natural History Society: Natural History Convention," Illinois State Agricultural Society, *Transactions*, III (1859), 638-39. The proceedings of the Illinois Natural History Society, 1858-60, were printed in the Illinois State Agricultural Society, *Transactions*, volumes III and IV. Charles D. Wilber edited and reprinted the proceedings as Illinois Natural History Society, *Transactions*, 2d. edition, series 1, volume I. No other volumes were published. Reports of the meetings of the Natural History Society appeared in *The Illinois Teacher*, volumes IV (1858), 258-59 and VI (1860), 253-62. Fragmentary accounts are in *The Prairie Farmer*, II (1858), 20, 24, 323, 328, 358, 387 and III (1859), 90 and IV (1860), 20, 36, 52. The Bloomington *Daily Pantagraph* also printed fragmentary accounts, July 1, 1858; December 21, 1861; November 16, 1865; June 28, 1866; December 20, 1867; January 10, 1868; November 27, 1869. These various accounts have been collated, and unless there is additional information in another source, the Agricultural Society, *Transactions* will be cited hereafter as INHS Proceedings, ISAgS, *Transactions*.

16 INHS Proceedings, ISAgS, *Transactions*, III, 639.

17 "George Vasey," American Academy of Arts and Sciences, *Proceedings*, XXVIII (1893), 401.

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21 *Ibid.*, 638.
22 *Ibid.*, 644-50.
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26 *Ibid.*, 650-61.
27 These conclusions are arrived at after reading the letters of Engelmann to and from his collectors, and from Gray to Engelmann. These letters are in the Missouri Botanical Gardens, St. Louis, Missouri.
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30 C. D. W., "Directions for the Study of Natural History," V (1859), 186-88.
31 II (1858), 387.
32 "George Vasey," *loc. cit.*, XXVIII (1893), 401-03.
33 Wilber, Report to Hovey, 407.
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35 Wilber, Report to Hovey, 407.
36 INHS Proceedings, ISAgS, *Transactions*, IV (1861), 539.
37 Wilber, Report to Hovey, 408.
38 Charles D. Wilber, ed., Illinois Natural History Society, *Transactions*, 2d. edition, series 1, volume I (Springfield, 1861), 145-47. Cited hereafter as Wilber, ed., INHS, *Transactions*. The museum was dedicated by the Natural History Society in December, 1861. Bloomington *Daily Pantagraph*, December 21, 1861.
39 Charles D. Wilber, "Report to President Hovey," Superintendent of Public Instruction, *Fourth Biennial Report for the Years 1860-62*. (1863), 83. Cited hereafter as Wilber, 2d Report to Hovey.
40 *Ibid.*
41 *Ibid.*
42 *Ibid.*
43 *The Prairie Farmer*, II (1858), 323. Perhaps it was this criticism that brought Wilber later to say, "Agriculture is natural history applied." Wilber, ed., INHS, *Transactions*, 4.
44 Wilber, 2d. Report to Hovey, 83.
45 INHS Proceedings, ISAgS, *Transactions*, III, 663.
46 Harlow B. Mills, "From 1858 to 1958," *loc. cit.*, 90-91.
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55 *Ibid.*, 671-75.
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60 *Ibid.*, 627-30.
61 *Ibid.*, 597-604.
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66 *Ibid.*, 565-80.
67 William C. Darrah, *Powell of the Colorado* (Princeton, 1951), 3046.
68 *Ibid.*, 47-79; Bloomington *Daily Pantagraph*, November 16, 1865.
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70 Marshall, *Grandest of Enterprises*, 93.
71 *Ibid.*, 78.
72 Bloomington *Daily Pantagraph*, June 30, 1866.
73 Superintendent of Public Instruction, *Biennial Report for 1864-66* (1867), 233.
74 Harlow B. Mills, "From 1858 to 1958," *loc. cit.*, 97. F. Garvin Davenport, "Natural Scientists and Farmers of Illinois, 1865-1900," Illinois State Historical Society, *Journal*, LI (1958), 360.
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76 State of Illinois, 25th General Assembly, *Public Laws* (1867), 21.
77 Morris, John Wesley Powell, Scientist and Educator, 40; Board of Education, *Proceedings* (1867), 1, 8.
78 Darrah, *Powell of the Colorado*, 80; Marshall, *Grandest of Enterprises*, 118-29. Professor Marshall is very critical of Powell's conduct, conveying the idea that Powell was self-seeking and used the Natural History Society and Normal University to promote his own interests. Darrah, *Powell of the Colorado*, 80, and Wallace E. Stegner, *Beyond the Hundredth Meridian*, 18, both admit that Powell sought the job because he was ambitious, and because he was offered larger opportunities at Normal. After he got the job as curator he saw how he could use his position for the advancement of science through making field trips, and, as leader of the expeditions, he would advance his own scientific reputation, but neither Stegner nor Darrah feel that he was self-seeking, although Stegner does say Powell was "politician and promoter, . . . superimposed on the natural scientist" (18). Morris, in his Master's thesis, John Wesley Powell, Scientist and Educator, dwells upon Powell, the good teacher and resourceful leader of field trips.
79 Darrah, *Powell of the Colorado*, 81-82.
80 Marshall, *Grandest of Enterprises*, 125.
81 *Ibid.*, 124-25; Bloomington *Daily Pantagraph*, January 25, 1868.
82 Marshall, *Grandest of Enterprises*, 127; Board of Education, *Proceedings* (1870), 6.
83 Bloomington *Daily Pantagraph*, January 10, 1868.
84 *Ibid.*, November 27, 1869.
85 Superintendent of Public Instruction, *Biennial Report, 1874-76* (1877), 324; Marshall, *Grandest of Enterprises*, 128.
86 Stephen A. Forbes, who succeeded Powell as head of the museum at Normal, makes these points, but adds a third: that it gave Powell a start on his career. Forbes, "A History of the Former State Natural History Societies of Illinois," Illinois State Academy of Science, *Transactions*, I (1908), 23.
87 Harlow B. Mills, "From 1858 to 1958," *loc. cit.*, 95. The most comprehensive biographical sketch is L. O. Howard's, "Biographical Memoir of Stephen Alfred Forbes, 1844-1930," National Academy of Science, *Biographical Memoirs*, XV (1932), 1-54.
88 Stephen A. Forbes to President Richard Edwards, Superintendent of Public Instruction, *Biennial Report, 1872-74* (1875), 143.
89 *Ibid.*, 144.
90 *Ibid.*, 145.
91 *Ibid.*, 146-47. A report of this meeting was published in *The Poplar Science Monthly*, V (1874), 128.
92 Stephen A. Forbes to President Richard Edwards, *loc. cit.*, 147-50.
93 Forbes, "A History of the Former State Natural History Societies of Illinois," Illinois State Academy of Science, *Transactions*, I (1908), 24.
94 *Constitution and Record of Organization of the State Natural History Society of Illinois* (Bloomington, 1879), 3. In 1875 had been formed the Agassiz Association, a national organization with local

and state branches, whose purpose was to encourage natural history interest among students and teachers. See Bates, *Scientific Societies in the United States*, 110. There is no evidence that the Illinois group was ever affiliated with the national organization.

95 *Constitution and Record of Organization of the State Natural History Society of Illinois.* Other officers were T. J. Burrill, Champaign, and H. M. Bannister, Chicago, vice-presidents; Homer M. Hibbard, Chicago, treasurer. S. H. Peabody, Champaign, and Cyrus Thomas, Carbondale, with the officers, constituted the executive committee.

96 *Ibid.*, 2.

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Manuscript received July 15, 1960.

A KEY TO THE ILLINOIS SPECIES OF *ICTALURUS* (CLASS PISCES) BASED ON PECTORAL SPINES

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The species of *Ictalurus* occurring in Illinois can be identified by using diagnostic characters found on the pectoral spine.

Macerated skeletons of the five species of fish comprising the genus *Ictalurus* in Illinois were used in this study. The material at hand consisted of 5 skeletons of *I. furcatus* ranging in total length from 8 to 31 inches; 202 skeletons of *I. melas*, 1 to 13 inches (total length); 20 skeletons of *I. natalis*, 2 to 8 inches (total length); 15 skeletons of *I. nebulosus*, 2 to 8.5 inches (total length); and 61 skeletons of *I. punctatus*, 3 to 26 inches (total length). The articulating end of the pectoral spine from each macerated fish was undamaged and the shaft of the spine was free of skin which permitted examination of the dentations. The terms used to describe the structures on the pectoral spine follow the terminology of Hubbs and Hibbard (1951).

I wish to extend sincere appreciation to Miss Susan M. Lohnes who made the drawings.

Description of the Pectoral Spine

The articular surfaces at the proximal end of the two pectoral spines articulate with the cleithrum and the coracoid (figure 1). Although the anteroventral emargination locks into the pectoral girdle, lateral movement of the spine is still possible.

Dentations are present on the posterior edge of the spine and may be antrorse (directed more or less distad), retrorse (directed proximad) or erect. The anterior edge of the spine may be armed with very fine serrations proximally and weak notches distally. The distal end, or the tip of the spine, is also called the end of the ossification by Hubbs and Hibbard (1951).

Several measurements and ratios were used to show differences between the various species. The *base line of the shaft* is here defined as the straight line formed by the pectoral spine when placed upright on the anterior edge of the spine. The *anteroventral emargination angle* is here defined as the angle formed by a line passing through the anteroventral emargination with the base line of the shaft. This angle appears to be an important diagnostic characteristic in the five species and does not undergo much variation in size due to the age of the fish.

The *ventral process-dorsal articulating surface distance* is the distance of the ventral process through the dorsal articulating surface. The greatest *thickness of the pectoral spine* is the distance through the anterior edge to the posterior edge of the spine across the basal recess. The *width of the dorsal articulating surface* is the distance through the widest part of this surface.

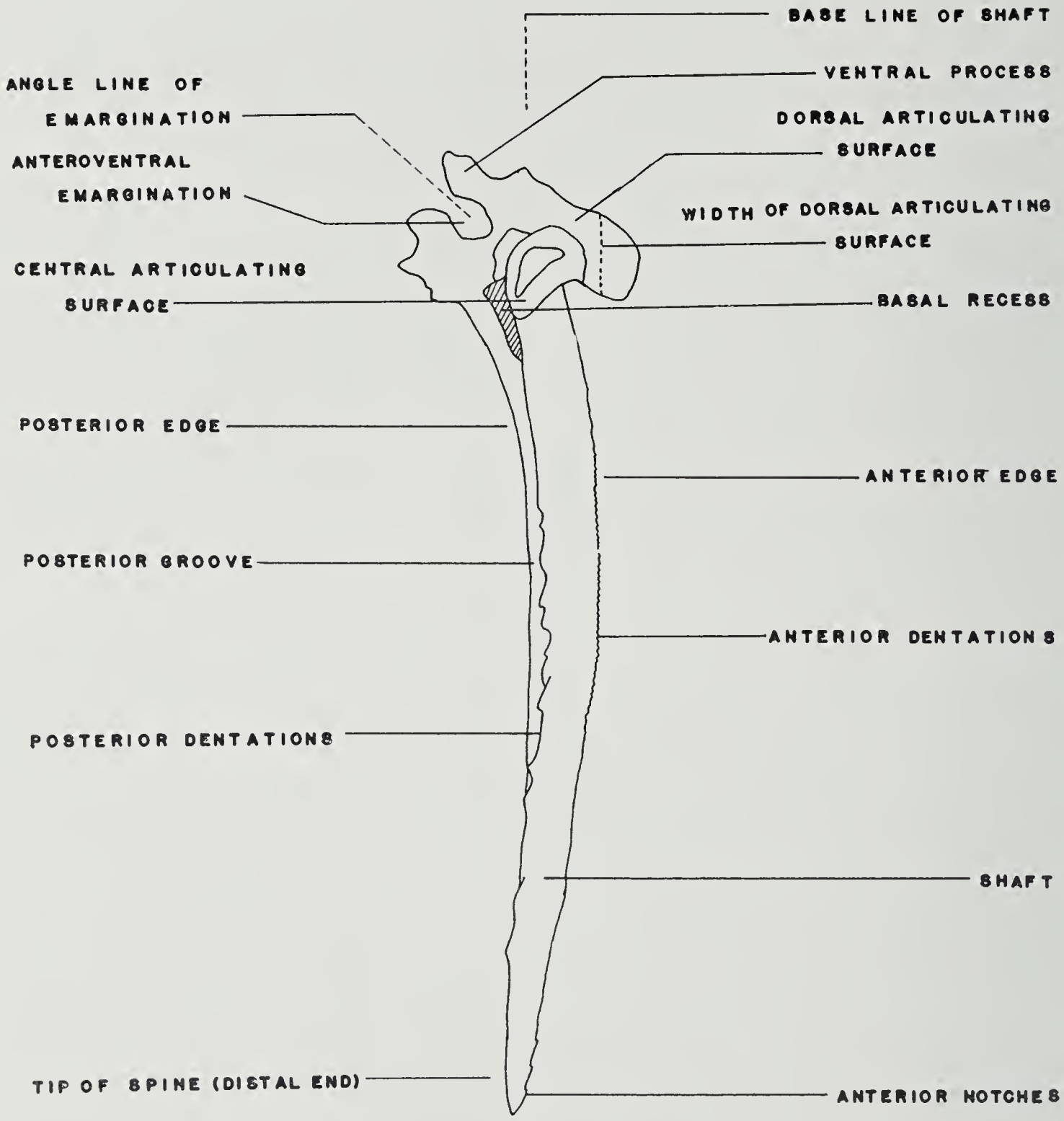

FIGURE 1. Lateral view of a generalized pectoral spine of *Ictalurus*.

Ictalurus punctatus (Rafinesque)

Dentations are present on both anterior and posterior edges of the pectoral spine (figure 2 A). The posterior dentations on the distal two-thirds of the shaft of the spine are retrorse and those on the proximal one-third of the shaft are antrorse. The posterior dentations are in the posterior groove. The anterior dentations are very fine serrations except for one or two small weak notches at the tip of the spine.

The basal recess is large; the length of the recess is greater than the width of the recess. The anteroventral emargination angle ranges between 43°-45°. The ratio of the ventral process-dorsal articulating surface distance to the spine length is 0.20-0.22; ventral process-dorsal articulating surface distance/spine thickness, 0.50-0.51; pectoral spine

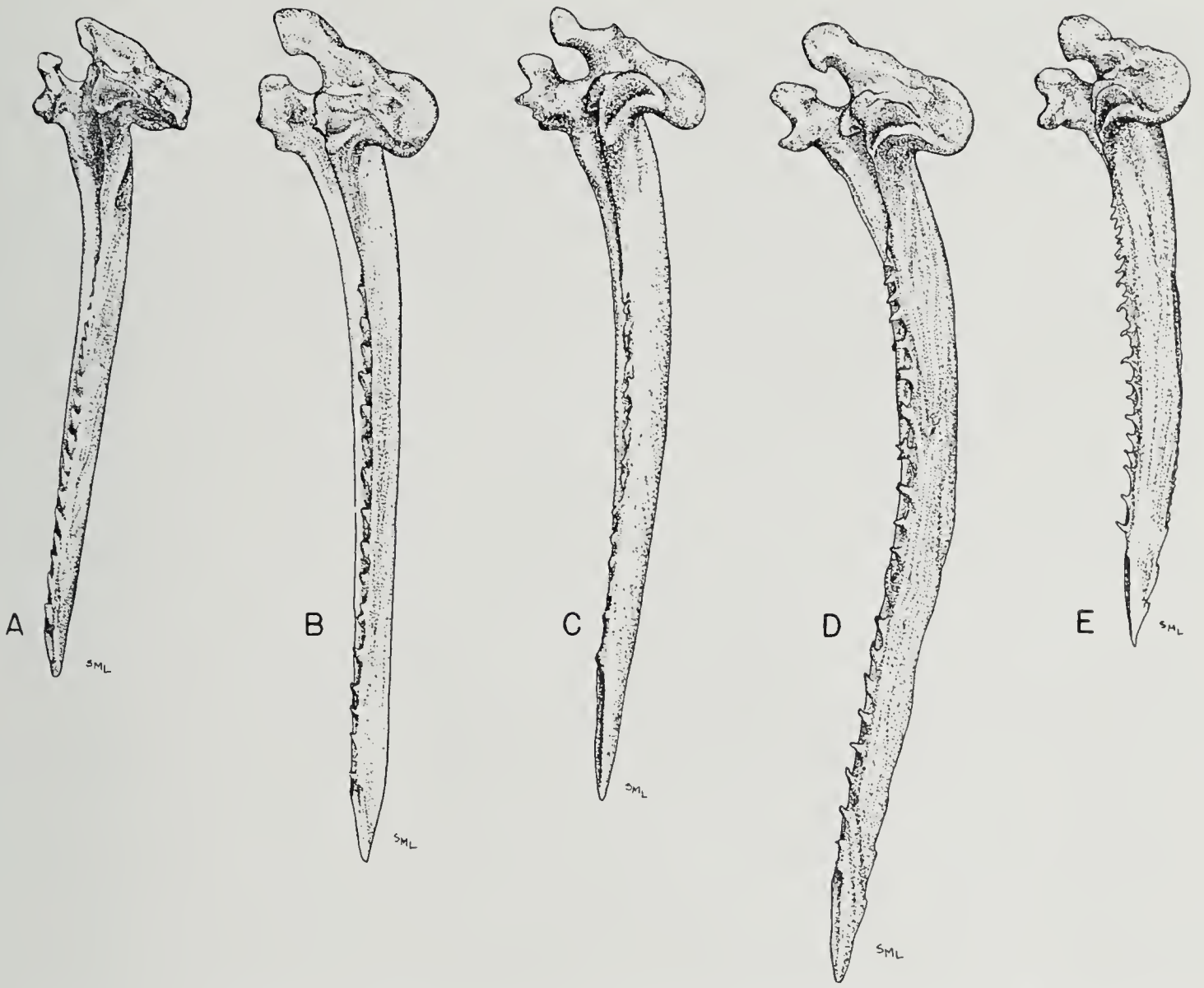

FIGURE 2.—Pectoral spines of (A) *Ictalurus punctatus*, 4x, (B) *Ictalurus furcatus*, 3x, (C) *Ictalurus melas*, 7x, (D) *Ictalurus nebulosus*, 4x, and (E) *Ictalurus natalis*, 8x.

thickness/spine length, 0.10-0.11; dorsal articulating surface width/spine thickness, 0.79-0.80; and dorsal articulating surface width/spine length, 0.12-0.15.

Ictalurus furcatus (LeSueur)

There are no dentations or notches on the anterior side of the spine (figure 2 B). The posterior dentations in the posterior groove are well developed retrorse teeth. The anteroventral emargination angle ranges between 43°-45°.

The ratio of the ventral process-dorsal articulating surface distance/spine length is 0.25-0.28; ventral process-dorsal articulating surface distance/spine thickness, 0.35-0.36; pectoral spine thickness/spine length, 0.07-0.09; dorsal articulating surface width/spine thickness, 0.61; and dorsal articulating surface width/spine length, 0.15.

Ictalurus melas (Rafinesque)

There are no dentations on the anterior side of the spine (figure 2 C), but a weak notch is occasionally present at the tip of the spine. This notch was present in less than 4% of the 404 spines examined.

The posterior dentations are weak and are located along the edge of the posterior groove rather than being in the posterior groove. Forbes and Richardson (1920) state that the posterior edge of the pectoral spine of this species is usually entire or slightly roughened and that 5 to 10 weak teeth occur only in adults. Dentations were present in all specimens examined which included young specimens 1.0 to 2.0 inches (total length). The number of teeth present on the posterior edge varied depending on the size of the fish. In specimens up to 5.0 inches (total length) the number of posterior dentations was 4 to 7. In specimens over 5.0 inches (total length) the number of posterior dentations was 8 to 12.

The anteroventral emargination angle ranged from 60°-65°. The ratio of the ventral process-dorsal articulating surface distance/spine length is 0.20-0.22; ventral process-dorsal articulating surface distance/spine thickness, 0.47-0.48; pectoral spine thickness/spine length, 0.11-0.13; dorsal articulating surface width/pectoral spine thickness, 0.74-0.75; and dorsal articulating surface width/pectoral spine length, 0.14-0.16.

Ictalurus nebulosus (LeSueur)

Dentations are present on both anterior and posterior edges of the spine (figure 2 D). The posterior dentations on the distal one-third of the shaft of the spine are retrorse, those on the middle one-third erect, and those on the upper one-third antrorse. The anterior dentations are very fine serrations except for three or four small weak notches at the tip of the spine.

The basal recess is small, the length of the recess being almost equal to the width of the recess. The anteroventral emargination angle ranged between 34°-36°. The ratio of the ventral process-dorsal articulating surface distance/spine length is 0.24-0.25; ventral process-dorsal articulating surface distance/spine thickness, 0.44-0.47; pectoral spine thickness/spine length, 0.08-0.10; dorsal articulating surface width/spine thickness, 0.74-0.76; and dorsal articulating surface width/spine length, 0.13-0.14.

Ictalurus natalis (LeSueur)

Dentations are present on both anterior and posterior edges of the spine (figure 2 E). The posterior dentations on the distal three-fourths of the shaft of the spine are retrorse and the posterior dentations on the proximal one-fourth of the shaft are antrorse. The anterior dentations consist of very fine serrations except for one or two small weak notches at the tip of the spine.

The basal recess is small, the length of the recess being almost equal to the width of the recess. The anteroventral emargination angle ranged between 34°-36°. The ratio of the ventral process-dorsal articulating surface distance/spine length is 0.27-0.28; ventral process-dorsal articulating surface distance/spine thickness, 0.52-0.57; spine thickness/spine length, 0.13-0.14; dorsal articulating surface width/spine thickness, 0.79-0.80; and dorsal articulating surface width/spine length, 0.17-0.18.

Key to Five Species of the Genus *Ictalurus*

1 A. Dentations present only on posterior side of the spine, or if present on anterior side, consisting of weak notches at tip of spine.... 2

1 B. Dentations present on posterior and anterior sides of spine; dentations on anterior side of spine consisting of very fine serrations; one to four weak notches may be present on anterior side at tip of spine..... 3

2 A. Posterior dentations located in posterior groove; edge of anterior side entire, without notch on shaft; anteroventral emargination angle 45° or less; ventral process-dorsal articulating surface distance/spine length 0.25-0.28; pectoral spine thickness/spine length 0.07-0.09; dorsal articulating surface width/spine thickness 0.61..... .....*Ictalurus furcatus*

2 B. Posterior dentations located on edge of posterior groove; single notch present on anterior side at tip of spine occasionally; anteroventral emargination angle 60-65°; ventral process-dorsal articulating surface distance/spine length 0.20-0.22; pectoral spine thickness/spine length 0.11-0.13; dorsal articulating surface width/spine thickness 0.74-0.75..*Ictalurus melas*

3 A. Basal recess large, length of the recess greater than the width of the recess; one or two notches may be present on anterior side at tip of spine; anteroventral emargination angle 45°; ventral process-dorsal articulating surface distance/spine length 0.20-0.22; pectoral spine thickness/spine length 0.11-0.12 .....*Ictalurus punctatus*

3 B. Basal recess small, length of recess almost equal to width; anteroventral emargination angle 35°; ventral process-dorsal articulating surface distance/spine length 0.24-0.28 4

4 A. Spine slender, pectoral spine thickness/spine length 0.08-0.10; ventral process-dorsal articulating surface distance/spine length 0.24-0.25; ventral process-dorsal articulating surface distance/pectoral spine thickness 0.44-0.47; dorsal articulating surface width/pectoral spine length 0.14; three or four small weak notches present on anterior side at tip of spine....*Ictalurus nebulosus*

4 B. Spine robust, pectoral spine thickness/pectoral spine length 0.14-0.16; ventral process-dorsal articulating surface distance/spine length 0.27-0.28; ventral process-dorsal articulating surface distance/spine thickness 0.52-0.57; dorsal articulating surface width/spine length 0.18; one or two small weak notches present on anterior side at tip of spine.....*Ictalurus natalis*

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NEW GENERA AND SPECIES OF THYSANOPTERA (TUBULIFERA: PHLAEOTHRIPIDAE) FROM ILLINOIS AND ALABAMA

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The following new genera of the Phlaeothripinae have in common the unusual characteristic of possessing two pairs of conspicuous epimeral setae; that is, there are two well-developed setae present on each epimeral sclerite on either side of the prothorax. This feature is shared by the Neotropical *Holcothrips* and *Phrasterothrips,* some *Acanthothrips,* several Oriental and Australian entities in the genera *Tolmetothrips, Austrothrips, Eothrips* and allies, and *Pselaphothrips,* as well as in a few genera belonging to the Megathripinae. It is apparently a characteristic of evolutionary convergence. Although useful in taxonomic analyses, it is not completely reliable, as forms are found, even within the same species or genus, which may have one of these pairs of setae considerably reduced. Although they key out well together, the two new genera described herein do not appear to be closely related.

The new species of *Hoplandrothrips* is from native Illinois prairie grasses and is not yet known elsewhere.

Diphyothrips, new genus

Head just slightly longer than broad, with weak, transverse striae. Eyes moderately small, shorter than combined lengths of antennal segments I and II, not ventrally prolonged. Ocelli present, moderately far apart, fore ocellus overhanging insertion of antennae. Antennae eight-segmented; segments I and II more or less symmetrical; segments III with basal half abruptly narrowed; segment VIII only slightly narrowed basally, broadly attached to segment VII. Postocular setae long. Maxillary stylets, when at rest position, extended far into the head and placed fairly close together within the center of the head. Mouth cone moderately long, broadly rounded.

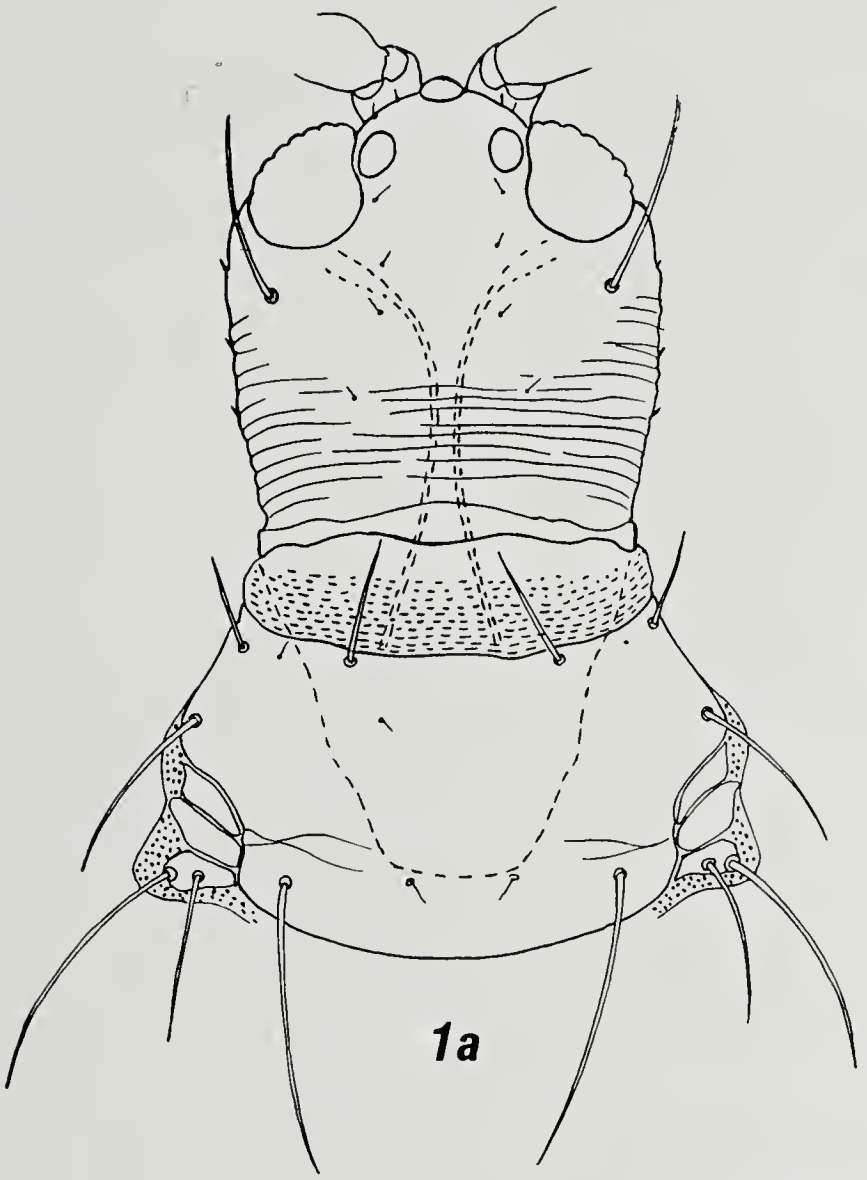
Prothorax shorter than head, nearly smooth. All major setae well developed, midlateral setae closer to epimeral suture than to anterolateral setae. Epimeral suture complete. Each epimeron divided into three parts, with two well developed setae. Praepectus apparently absent. Metascutum nearly smooth medially with weak elongated reticulations that tend to become longitudinal striations laterally, lacking long setae; mesopraesternum band-like, completely separated by a suture from the mesosternum. Fore femora not particularly enlarged. Fore wings of even width throughout, with accessory fringe cilia.

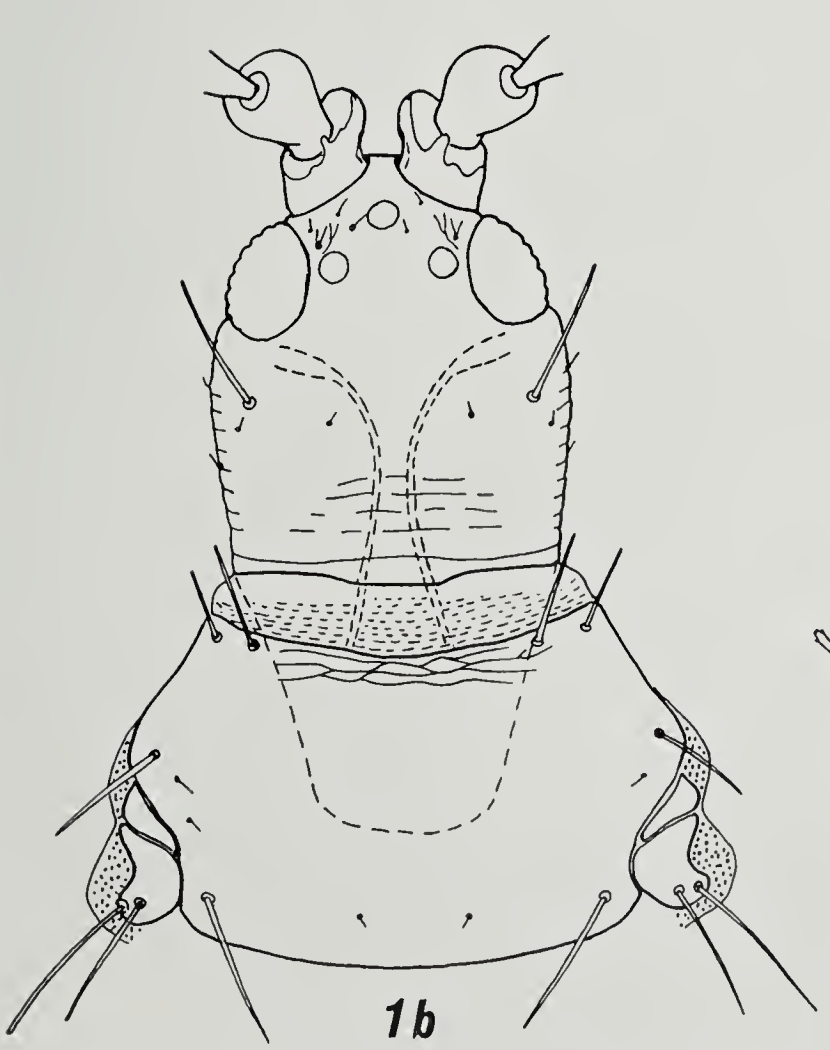
Pelta small, triangular to bell-shaped. Wing holding setae relatively slender, curved to nearly sigmoidal. Abdominal tergite II at sides not especially fractured into small stipple-like platelets. Abdominal tergite IX with major posterior setae much longer than tube in female; condition in male unknown. Tube slightly shorter than head; terminal setae shorter than tube.

Type-species.—*Diphyothrips morainensis,* new species.

The division of the epimeral plate into three parts is a unique characteristic for this genus.

Of the genera of Phlaeothripinae occurring in the Americas, those which have two pairs of epimeral setae differ from *Diphyothrips* in important respects: *Phrasterothrips*





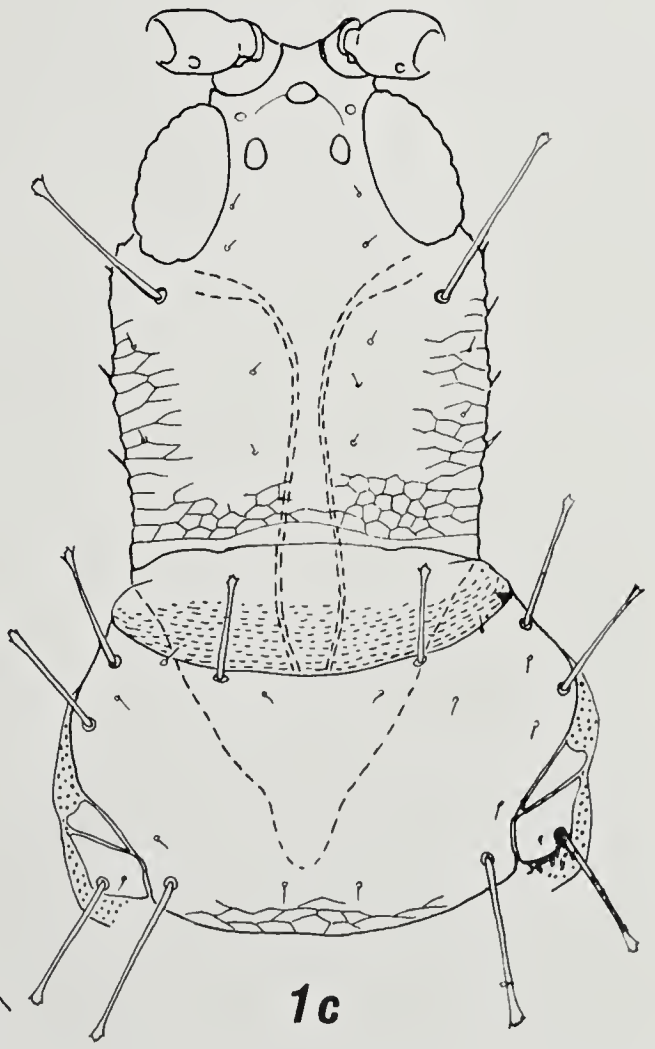


FIGURE 1.—Dorsal view of head and prothorax of 1a, *Diphyothrips morainensis* n. sp.; 1b, *Acrosothrips asymmetricus* (Watson); and 1c, *Hoplandrothrips lateralis* n. sp.

has the midlateral prothoracic setae placed closer to the anterolateral setae than to the epimeral suture, whereas in *Diphyothrips* these lateral setae arise close to the epimeral suture; *Acrosothrips* has antennal segments I and II strongly asymmetrical in contrast to the nearly symmetrical condition found in *Diphyothrips*; and *Holcothrips* is said to have the dorsal surface of the head reticulate, the post ocular setae very short, the major prothoracic setae dilated, and the fore wings lacking accessory setae—characteristics which are not found in *Diphysothrips*.

Diphyothrips morainensis,
new species

Female (macropterous). — Length nearly 2 mm. Color dark brown. Antennal segment III, fore tibiae and all tarsi, yellowish brown. Subintegumental pigment red. All body setae pale yellow. Wings colorless except light brown at base including scale of forewing.

Head as in figure 1a. Post ocular setae pointed. Ocellar setae minute. Antennal segment III with one outer sense cone, which is about 10 μ long, and no inner sense cone. Antennal segment IV with one outer sense cone, which is about 24 μ long, and one inner sense cone, which is about 16 μ long.

Prothorax, figure 1a, with all major setae long and blunt at tips. Anteromarginal setae longer than anterolateral setae. Posteromarginal setae longest, longer than length of prothorax. Pterothorax with all lateroventral setae pointed. Fore tarsi unarmed. Fore wings with 11 to 13 accessory fringe cilia.

Abdomen with pelta triangular to slightly bell shaped, not abruptly expanded near posterior margin. Lateral abdominal setae becoming progressively longer on segments II to IX, only lateral setae on segment IX longer than tube. Abdominal tergite IX with all long major setae pointed at tips.

Measurements in μ: Holotype ♀, paratype ♀. — Head length 228, 228, greatest width, just behind eyes 227, 216; compound eye dorsal length 64, 60, dorsal width 59, 56; post ocular seta length 120, 110; antenna total length, including membranes 435, . . . ; antennal segments, exclusive of membranes:

	length	*width*
I	32, 29	39, 38
II	55. ..	36, ..
III	64, 60	36, 34
IV	54, 52	38, 38
V	59, 56	36, 36
VI	56, 53	36, 36
VII	60, 55	28, 28
VIII	41, 41	16, ..

Pronotum length 147, 135, width 280, 280; anteromarginal seta length 64, 56; anterolateral seta length 50, 46; outer epimeral seta length 160, 152; inner epimeral seta length 88, 75; posteromarginal seta length 168, 160; fore wing length 886, 866, mid width 88, 74; major posterior setae on abdominal segment IX each length 250, 260; abdominal segment X (tube) length 240, 240, width at base 88, 80, apical seta length 160, 145.

Holotype. — Female; Elgin, Illinois; September 21, 1961; L. J. Stannard; swept from grasses on morainal hill prairie along Shoefactory Road. Paratype.—1♀: same data as for holotype except July 28, 1953.

In general form, *D. morainensis* resembles some species in *Liothrips* subgenus *Rhynchothrips*, differing especially in having a shorter and more broadly rounded mouth cone and in bearing two pairs of epimeral setae. Possibly even in *Rhynchothrips* there is a latent tendency for the production of two pairs of epimeral setae because Hood (1912) illustrated *Rhynchothrips dentifer* as having an additional well-developed seta on one side only in addition to the usual one pair of epimeral setae.

The rare *Liothrips* (*Rhynchothrips*) *longitubus* Hood is superficially like *D. morainensis;* both have fairly long tubes and many major setae on abdominal segments longer than the tube length. The two can be easily distinguished, however, be-

cause *longitubus* not only lacks the extra well developed setae on the prothorax but also antennal segment IV and V are yellow not brown as in *morainensis*.

Acrosothrips, new genus

Head, figure 1b, slightly longer than broad, nearly smooth. Eyes moderately small, shorter than the combined lengths of antennal segments I and II. Vertex broad at the apex between the antennae. Ocelli present, moderately far apart, fore ocellus not overhanging. Antennae eight-segmented; segments I and II each produced on the inner ventral apex making these segments asymmetrical; segment III gradually narrowed to base; intermediate segments moderately small; segment VIII slender, not broadly attached to segment VII. Postocular setae long. Maxillary stylets, when at rest position, extend far into the head and placed fairly close together within the center of the head. Mouth cone moderately long, broadly rounded.

Prothorax, figure 1b, not quite as long as head, nearly smooth. All major setae well developed, mid lateral seta closer to epimeral suture than to anterolateral seta. Epimeral suture complete. Each epimeron divided into two parts, with two well developed setae. Praepectus apparently absent. Metascutum faintly marked by longitudinal striations, without extremely long setae. Mesopraesternum completely separated by a suture from the mesosternum. Fore femora enlarged. Fore wings of uniform width throughout, without accessory fringe cilia.

Pelta small, bell-shaped. Wing-holding setae slender, mostly sigmoidal. Abdominal tergite II at extreme sides fractured into small stipple-like platelets. Abdominal tergite IX with major posterior setae much longer than tube. Tube (segment X) shorter than head; terminal setae shorter than tube.

Type-species.—*Trichothrips asymmetricus* Watson (1937:8).

The asymmetrical form of antennal segments I and II is diagnostic, figure 1b.

Possibly this monobasic genus is a derivative of the *Plectrothrips* line. The shape of the head, the slender form of antennal segment VIII, the enlarged fore femora, and the condition of the sides of abdominal tergite II which is fractured into tiny platelets are, characteristics suggestive of *Plectrothrips* and its allies.

From those in the subfamily Phlaeothripinae that occur in the Americas, and which have two pairs of well-developed epimeral setae, *Acrosothrips* may be distinguished by the negative feature of a lack of accessory fringe cilia on the fore wings.

The sole species, *A. asymmetricus*, has not been recorded since the protologist's report.

Hoplandrothrips lateralis, new species

Female. (macropterous). — Length, distended, about 2.5 mm. General color dark brown. Tibiae and median streak on each of abdominal tergites II to VIII yellowish brown. Tarsi yellow. Antennal segments I, II, and VIII brown, segment II lighter at tip, segments III yellow becoming clouded with brown in apical third, segments IV to VII yellow basally, at least in the region of the pedicel. Fore wings pale yellow. Body with much red subintegumental pigment.

Head, figure 1c, moderately long, one-fourth longer than broadest width which is just behind eyes. Cheeks with three or four pairs of small spines, the basal pair being the most prominent. Dorsum of head with hexagonal reticulations basally, and with modified, somewhat transverse reticulations or anastomosing striae laterally; center of head smooth. Post ocular setae long, dilated. Antennal segment III asymmetrical, longest segment, subvasiform, with two outer and one inner sense cone; segment IV ovoid, pedicellate, with two outer and two inner sense cones; segments V, VI, and VII slender, pedicellate; segment VIII fairly broadly attached to segment VII, with a slight indication of a pedicel. Maxillary stylets, when retracted, extending within the head to the eye region, nearly touching in the center

of the head. Mouth cone pointed.

Prothorax, figure 1c, with dorsal surface smooth except the posterior central margin which is reticulate. All major setae well developed, dilated; anteromarginal pair each shorter than anterolaterals. Epimeral sutures complete. Praepectus absent.

Pterothorax widest part of body; metanotum hexagonally reticulate medially. Mesopraesternum degenerate medially, divided into three parts. Fore femora and tibiae not armed. Fore tarsi each with a moderate tooth. Fore wings narrow, slightly indented in the middle, with 9 accessory fringe cilia, basal wing setae subequal, more or less in line, dilated.

Abdomen slender. Pelta "derby" shaped reticulate. Tergites II to VII each with two pairs of sigmoidal wing-holding setae; tergites II to VIII with lateral setae dilated. Tergite IX with major posterior setae shorter than tube, middle pair dilated, lateral pair pointed at tip. Tube much shorter than head; terminal (anal) setae longer than tube.

Measurements in μ: Holotype ♀, paratype ♀, from Donovan, Illinois.—Head length 280, 282, greatest width, just behind eyes 208, 192; compound eye dorsal length 88, 96, dorsal width 56, 48; post ocular seta length 93, 96; antennae total length, including membranes 420, 416; antennal segments, exclusive of membranes:

	length	*width*
I	24, 32	34, 34
II	43, 40	32, 30
III	76, 72	36, 34
IV	72, 64	34, 32
V	64, 64	27, 26
VI	56, 56	24, 23
VII	50, 51	24, 21
VIII	32, 32	14, 11

pronotum length 144, 142, width 320, 286; anteromarginal seta length 50, 48; anterolateral seta length 80, 64; mid lateral seta length 74, 53; epimeral seta 80, 72; posteromarginal seta length 91, 96; fore wing length 920, 936, mid width 50, 54; three pairs of basal fore wing setae, each length 70 to 80, 64 to 72; abdominal tergite IX, major mid posterior seta 160, 174; abdominal segment X (tube) length 168, 176, width at base 72, 70; apical seta length 240, 256.

Male.—Not yet positively associated.

Holotype.—Female; Seymour, Illinois; November 13, 1953; Atcheson and Stannard; from clump of *Andropogon gerardi*. Paratypes.—1♀; Donovan, Illinois; October 21-25, 1962; McCollum and Roberts; *Andropogon* sod. 2♀♀; Galton, Illinois; October 22, 1959; L. J. Stannard; grass piles. 1♀; Danville, Illinois; November 1, 1942; H. H. Ross; decayed stump. 1♀; Clarksville, Illinois; June 14, 1950; Sanderson and Stannard. 1♀; Glendale, Illinois; November 7, 1947; Ross and Burks; debris in pine plantation.

This species is similar to *Hoplandrothrips xanthopus*. In the female sex, *H. lateralis* differs principally in having a longer head and in having the major posterior lateral setae on abdominal tergite IX pointed. In addition, *H. lateralis* may be similar to *H. scutellaris*. *Hoplandrothrips scutellaris* was described in the protolog as having, as does *H. xanthopus*, all the major posterior setae on abdominal tergite IX dilated. Another grass species, *H. uzeli*, known in Illinois in the Wabash Valley, has antennal segment VIII strongly pedicellate, and the major mid posterior setae on abdominal tergite are pointed, not dilated — two characteristics that readily distinguish it from *H. lateralis*.

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SUPPLEMENTARY VITAMINS IN EXPERIMENTAL PORPHYRIA

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Acute intermittent porphyria is an inherited metabolic disorder presenting a varied symptomatology, commonly abdominal pain and an ascending paralysis. Chemically, the disorder is characterized by an accumulation of porphyrins and porphyrin precursors in the liver and an elevated excretion of these compounds, principally porphobilinogen, in the urine (Sachs, 1931, and Westall, 1952). Duesberg (1932) reported an elevated porphyrin excretion in a patient receiving allylisopropylacetylcarbamide [Sedormid]. This observation suggested to Schmid and Schwartz (1952) a means of experimentally producing porphyria. In recent years other investigators have used Sedormid, or a water soluble analogue, allylisopropylacetamide, abbreviated as AIA, to induce an experimental porphyria of the acute intermittent type in rabbits, rats and chick embryos (Benard, et al., 1953, and Labbe, et al., 1954). However, it is possible that in the genetically determined human type of acute intermittent porphyria, the biochemical mechanism responsible for porphobilinogenuria may not be the same as that produced by a chemical such as Sedormid or AIA. The genetic abnormality would be expected to have a single locus of effect (Giraud, et al., 1960), whereas the chemically induced malfunction possibly has a multiple locus.

It was noted that during the period of experimental porphyria induction in albino rats, they became very lethargic, and their consumption of food and water, offered *ad libitum*, dropped to zero. Remembering that AIA is structurally related to the barbiturate family, and during these experiments was administered twice daily for three consecutive days, this is not surprising. Therefore we investigated malnutrition in experimental animals as a possible complicating factor in drug induced porphyria experiments.

Methods and Materials

Four groups of male Wistar rats were used in this study, with five animals in each group. Porphyria was induced and maintained by the subcutaneous injection, twice daily for three consecutive days, of 25 mgm of AIA in 1 cc of warm, isotonic saline.

The first group was given AIA and fed by stomach tube once daily with 3.5 cc of an aqueous solution containing 4 g of glucose, 10 mgm of thiamine, 5 mgm of riboflavin, 30 mgm of niacin, 30 mgm of pyridoxine and 30 mgm of vitamin C. A second group was given AIA, and fed by stomach tube once daily with 3.5 cc of an aqueous solution con-

taining only the B and C vitamins. The third group were deprived of all food and water except the glucose and B and C vitamin solution fed to group one, also delivered by stomach tube. Finally, the fourth group was untreated, and starved for the duration of the experiment.

The animals were weighed before starting the experiment, and daily during the experiment. Following three days of treatment, the animals were sacrificed by cervical separation. The livers were removed after the method of Rokitansky, blotted upon filter paper, and weighed. These data are summarized in Table 1.

Observations

The average weight loss of the starved animals was the same, and the percent weight loss almost the same as that of the porphyric rats force fed a vitamin B supplement. However, the livers of the rats of both porphyric groups showed over a two-fold increase in weight over those of the normal starved group, and almost the same increase over the livers of the normal starved group force fed with glucose and vitamins. The porphyric animals that were force fed glucose and vitamins suffered the least loss of weight, and the normal animals fed the identical ration a 1.4% greater loss. The starved animals lost more weight than the normal animals that were fed, with a large increment of this loss reflected in the sacrifice of liver carbohydrate stores. The porphyric rats, which were fed upon vitamins only, lost more weight than all of the other groups and exhibited the greatest hepatic enlargement.

Discussion

When the liver is healthy, porphyrins are excreted harmlessly into the bile; when diseased, they are retained in the blood and symptoms are produced (Sherlock, 1955). Inasmuch as animals treated with AIA become lethargic and do not feed, it was postulated that malnutrition might be one of the factors contributing to the hepatic enlargement re-

Table 1.—Summarization of the Weight of Livers and Changes in Body Weight of the Four Groups of Rats.

	AIA-Treated		Non-Treated	
	Glucose vitamins	*Vitamins*	*Glucose vitamins*	*Starved*
Average starting weight of each group	290 gms	287 gms	295 gms	293 gms
Average finishing weight of each group.....	243 gms	232 gms	243 gms	238 gms
Average weight loss for each group	47 gms	55 gms	52 gms	55 gms
Percent weight loss for each group ...	16.2%	19.0%	17.6%	18.9%
Average liver weight for each group ...	13 gms	13.3 gms	8 gms	6.2 gms

sponse to the drug. Vitamins of the B complex enter into several of the enzyme systems present in the liver; ascorbic acid is necessary for the formation of intercellular substances. Hence it was postulated that an adequate supply of these metabolic catalysts, coupled with sufficient glucose to supply the immediate caloric requirements of the starving animal, would protect the liver from the increase in size commensurate with experimental porphyria.

The results indicate that the vitamin and glucose therapy had a beneficial effect upon the body's general economy. These animals lost less weight than any other group. The starved animals lost less weight than all others, the glucose and vitamin feeding protecting the normal group. However, energy and vitamins are obviously insufficient to prevent some loss, and it is thought that a protein should have been added to the diet.

The porphyric rats fed on vitamins alone suffered the greatest loss of weight as well as having the most enlarged livers, while the AIA treated animals fed upon sugar and vitamins exhibited greatly enlarged livers. It is thought that the hepatic effects of experimentally induced porphyria will not be ameliorated by fortifying the diet with B complex and C vitamins, and using glucose to supply the calculated energy requirements of the animal.

Acknowledgments

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VEGETATION-SOIL RELATIONSHIPS IN HILL PRAIRIES

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While much of the original prairie of Illinois has been converted to cropland, many small relict hill prairies persist on steep, usually south-facing slopes high above the Illinois and Mississippi Rivers. The similarity and persistence of these grassland stands make their study interesting and informative. Other than Evers' (1952) extensive floristic study of many of these prairies and the work of Kilburn and Ford (1962), little has been done to analyze vegetational and environmental features of these unique types of vegetation. This study reports soil-vegetation relations on six of these prairies located on the Principia College Campus, Sec. 20 T6N R11W, Jersey County, Elsah, Illinois. The nomenclature follows Fernald (1950).

Material and Methods

Vegetational information was recorded from plots 10 m by 10 m. In these square plots some 10 m^2 quadrats were established in a regular pattern (Warren, 1962), and frequency and coverage (Oosting, 1953) data were taken from them. One plot was established in approximately the center of each of the six prairies. The prairies covered less than one-half acre, and most were separated by small forested ravines. All were within a single section above the Mississippi River bluffs.

In each plot the slope percentages, the vertical drop per 100 feet horizontally, were averaged from two readings with meter stick and level. Six soil samples were collected in each plot, two each at the one, two and three foot levels, and were analyzed by the Bouyoucos Method.

Results

Slope averages varied from 17.3% to 56.3%, with an average of 32.8% (Table 1). Soil analyses are given in Table 2. All soils were extremely sandy and low in clay content. The averages for sand at all levels varied from 78.8% to 85%. It can be seen that the sand percentage decreases with depth in all cases, while the silt percentage increases. No trend is evident with the small amounts of clay present.

Table 1.—Percent Slope Measurements.

Prairie	*Top*	*Middle*	*Bottom*	*Average*
Amelanchier	13	32	37	27.3
Black Widow	57	65	47	56.3
Cone Flower	21	30	37	29.3
Sumac	9	10	33	17.3
Osage Bluff (right)	34	30	45	36.3
Osage Bluff (left)	17	50	33	33.3

TABLE 2. Soil Texture Percents in Hill Prairies at Depths of one, two and three Feet.

Prairie	Sand				Silt				Clay			
	1	2	3	Avg.	1	2	3	Avg.	1	2	3	Avg.
Amelanchier	89.8	84.8	82.6	85.7	9.0	12.7	15.0	12.2	1.3	2.5	2.4	2.1
Black Widow	85.3	81.5	80.1	82.3	13.4	17.2	18.2	16.3	1.4	1.4	1.8	1.5
Cone Flower	82.2	79.9	80.9	81.0	15.9	18.8	17.6	17.4	2.0	1.4	1.6	1.7
Sumac	83.9	78.8	73.8	78.8	14.9	20.7	25.4	20.3	1.3	.6	.8	.9
Osage Bluff (right).....	85.3	86.3	83.4	85.0	14.1	13.2	16.2	14.5	1.6	.5	.5	.9
Osage Bluff (left).....	85.8	83.8	81.8	83.8	14.1	15.9	17.7	15.9	.2	.4	.6	.3

TABLE 3.—Coverage Percents for Predominant Hill Prairie Plants and Bare Soil at Each Locality.

	Prairies						
Plant	*Amelanch.*	*Black W.*	*Cone Fl.*	*Sumac*	*Osage-R*	*Osage-L*	*Avg.*
Andropogon scoparious	62.0	43.5	54.0	45.0	52.0	40.5	49.5
Bouteloua curtipendula	0.0	12.5	1.0	20.2	9.5	16.1	9.9
Panicum oligosanthes	0.9	0.1	2.6	1.0	0.6	0.5	0.9
Lespedeza capitata	1.0	2.0	4.6	2.9	1.5	3.6	2.6
Lespedeza intermedia	0.0	1.2	0.5	0.9	4.5	5.2	2.0
Oxalis violacea	0.0	0.0	0.8	0.2	0.2	0.1	0.2
Houstonia nigricans	3.5	0.7	1.0	1.3	3.3	3.9	2.3
Erigeron strigosus	0.0	0.0	0.2	0.0	4.2	3.3	1.3
Senecio plattensis	0.0	5.6	0.3	6.3	0.0	0.0	2.0
Scutellaria parvula	0.8	0.6	0.2	0.0	0.4	0.9	0.5
Penstemon pallidus	1.6	0.3	2.1	3.8	0.9	0.2	1.5
Ruellia humilis	0.7	0.3	00.2	0.0	0.8	0.1	0.4
Other species	4.4	6.8	15.0	17.2	14.7	15.4	12.3
Bare soil	20.1	20.5	12.0	1.2	3.3	6.2	10.5

TABLE 4. Frequency Distribution Percentages for Predominant Hill Prairie Plants. Figures for each prairie based on ten m^2 quadrats.

	Prairies						
Plant	*Amelanch.*	*Black W.*	*Cone Fl.*	*Sumac*	*Osage-R*	*Osage-L*	*Avg.*
Andropogon scoparius	100	100	100	100	100	100	100
Bouteloua curtipendula	0	50	10	80	100	100	57
Panicum oligosanthes	40	30	50	20	30	10	30
Lespedeza capitata	100	50	100	100	80	60	82
Lespedeza intermedia	0	60	30	60	80	80	52
Oxalis violacea	10	20	70	10	70	40	37
Houstonia nigricans	100	90	90	40	90	90	83
Erigeron strigosus	0	0	20	0	90	70	30
Senecio plattensis	0	90	20	80	0	0	32
Scutellaria parvula	40	40	30	0	30	20	27
Penstemon pallidus	50	30	60	40	40	10	38
Ruellia humilis	40	30	20	0	50	10	25

The vegetational data (Tables 3 and 4) show that little bluestem (*Andropogon scoparius*) clearly dominates all prairies with coverage values ranging from 40.5% to 62%, and frequency values of 100% in all cases. No other plant has coverage and frequency values approaching these figures, although side oats grama (*Bouteloua curtipendula*) has one hundred percent frequencies in half the plots and coverage values of more than 9% in four of the plots. In the other two plots *Bouteloua* is rare. Frequency values exceeding forty percent were found in all plots for both *Lespedeza capitata* and *Houstonia nigricans*. Values for the other plants are less consistent than these.

Discussion

The data reveal that, on these steep, south-facing slopes with a very sandy soil, the assemblage of prairie plants and dominance of *A. scoparius* resembles the xeric prairies of Curtis (1959). Many typically more mesic prairie species were recorded, including *Andropogon gerardi* and *Sorghastrum nutans*, but their occurrence was not consistent. All species sampled are recorded by Evers (1955).

The high sand content of these soils apparently favors the persistence of prairie species. Coupled with high temperatures and prevailing winds on these south-facing and river-facing slopes, the environment favors prairie vegetation even though oak-hickory forest covers all undisturbed upland and north-slope habitats in the area.

Despite the dry and somewhat hostile environment, trees and shrubs do invade the prairies from the forested draws or ravines which dissect the slopes. These plants build up a forest environment of leaf mulch and forest ground cover, and spreading branches. The forest extends into the prairie in two ways: by establishment of seedling plants in this forest environment and by root sprouts (*e.g. Rhus glabra* and *Cornus drummondi*). The end result is a gradual overwhelming of the prairie vegetation and loss of the prairie species. This indicates that, in the absence of fire, the prairie is subclimax and the successional climax consists of forest or woodland vegetation.

Summary

Sampling of six small hill prairies overlooking the Mississippi River in Jersey County, Illinois, shows that the general aspect of each is south-facing, the slope average is 30%, and the soil is very sandy. The vegetation is strongly dominated by little bluestem, although several other prairie forbs and grasses frequently occur there.

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CYCLIC CARBONATES AND THIOCARBONATES

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As a compound carbonic acid exists to a slight extent in equilibrium with its decomposition products, carbon dioxide and water:

$$H_2CO_3 = H_2O + CO_2$$

Pauling (1960:327) states that the ratio of dissolved carbon dioxide molecules to carbonic acid molecules is about 25 to 1. This would lead to a true value for the ionization constant of about 2×10^{-4}. Apparently, then, carbonic acid is somewhat stronger than acetic acid. The instability of carbonic acid can be attributed to the fact that the molecule is a gem-diol, a type normally decomposed with loss of water. In spite of the instability of the acid itself, many derivatives can be prepared through the use of the anhydride, CO_2, the double acid chloride, phosgene, $COCl_2$, and the double amide, urea, $CO(NH_2)_2$. Likewise the thioacids, monothiocarbonic acid, HOCOSH, dithiocarbonic acid, $O{=}C(SH)_2$, and trithiocarbonic acid, $S{=}C(SH)_2$, are unstable, but their anhydrides, carbonyl sulfide, COS, and carbon disulfide, CS_2, are known as are the acid chloride, thiophosgene, $S{=}CCl_2$, and the amide, thiourea, $S{=}C(NH_2)_2$.

Phosgene was first prepared in 1812 by Sir Humphrey Davy by the combination of carbon monoxide and chlorine in sunlight in the presence of charcoal:

$$CO + Cl_2 \xrightarrow[h\gamma]{C} COCl_2.$$

The name phosgene was chosen because the substance had its origin in light. This method is still used commercially, activated charcoal being used. The cast iron catalyst chamber is thoroughly cooled with water before the gases are admitted. About 80% conversion occurs on the first pass. In a second chamber the process is completed at elevated temperatures.

Typical of acid chlorides phosgene will react with ammonia, water, and alcohols. With a monofunctional alcohol, such as ethanol, the reaction proceeds through the chlorocarbonate (The chlorocarbonates are also named chloroformates since they are esters of the hypothetical acid, chloroformic acid. ClCOOH.) stage to the dialkyl carbonate:

$$COCl_2 + C_2H_5OH \rightarrow COClOC_2H_5 + HCl$$

$$COClOC_2H_5 + C_2H_5OH \rightarrow CO(OC_2H_5)_2 + HCl$$

Alcohol is added to commercial grades of chloroform to remove the phosgene which results when the chloroform stands in contact with air. If the ethyl chlorocarbonate is treated with ammonia instead of excess alcohol, urethane results:

$$\underset{}{COClOC_2H_5} + 2NH_3 \rightarrow \underset{\text{urethane}}{CONH_2OC_2H_5} + \underset{}{NH_4Cl}$$

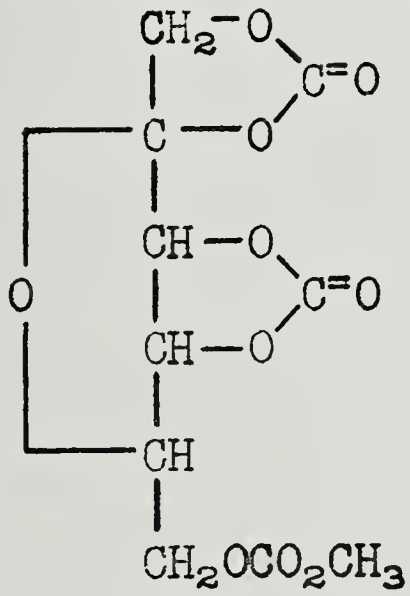
If a glycol be substituted for the monofunctional alcohol in the reaction with phosgene, a cyclic carbonate is produced:

$$HOCH_2CH_2OH + COCl_2 \rightarrow \underset{\text{ethylene carbonate}}{(CH_2O)_2CO}$$

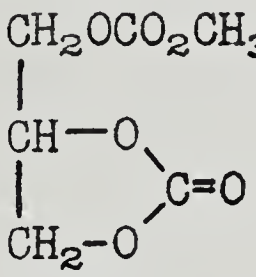
Nemirowsky (1883) was able to produce ethylene carbonate in good yield by passing a stream of phosgene through ethylene glycol at ordinary temperatures and pressures. The carbonate is also produced from ethyl chloroformate and the disodium derivative of glycol:

$$NaOCH_2CH_2ONa + COClOC_2H_5 \rightarrow (CH_2O)_2CO + C_2H_5ONa + NaCl$$

This method was used by Allpress and Haworth (1924) to produce sugar carbonates. For example fructose, in aqueous solution, reacts with alkyl chloroformates at 0°C. to produce sugar carbonates such as monocarbomethoxyfructose dicarbonate:



Under similar conditions glycerol yields monocarbomethoxyglycerol carbonate:



These compounds are completely hydrolyzed by acids, alkalis, and sodium alkylates.

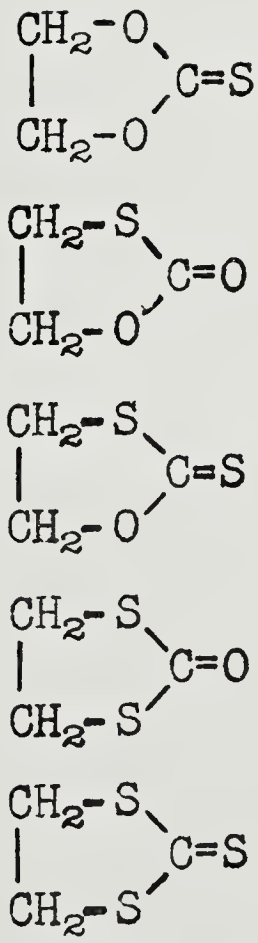
The first thiocarbonates were reported by Debus (1850) who prepared diethylthioncarbonate, $SC(OC_2H_5)_2$ by heating ethyl xanthate. Some diethylthionthiocarbonate is formed at the same time:

$$C_2H_5OCSSNa \rightarrow CS(OC_2H_5)_2 + CS(OC_2H_5)SC_2H_5$$

He made the trithiocarbonate by the action of thiophosgene on sodium ethyl mercaptide:

$$2\,C_2H_5SNa + CSCl_2 \rightarrow CS(SC_2H_5)_2 + 2NaCl$$

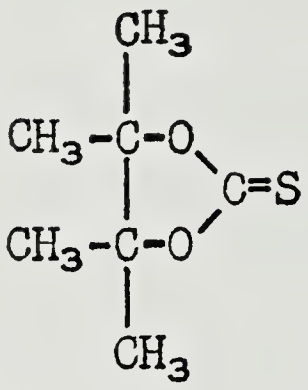
It is apparent that five different cyclic thiocarbonates can be derived from ethylene or its symmetrical derivatives:



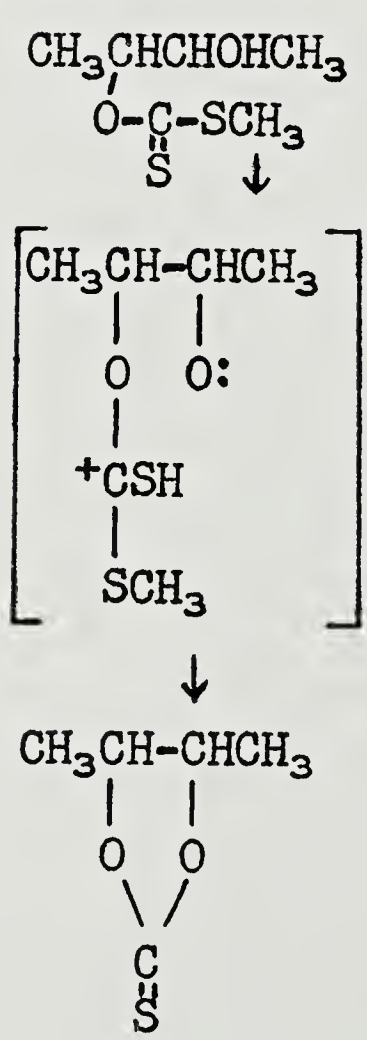
With unsymmetrical derivatives or with fused rings additional isomeric forms may be deduced.

Fomin (1935) showed that the pinacol derivative of methyl xanthate, $Me_2C(OCS_2Me)C(OH)Me_2$, is decomposed in the process of forma-

tion without separation of COS and with the evolution of MeSH to give the stable tetramethylethylene thiocarbonate:



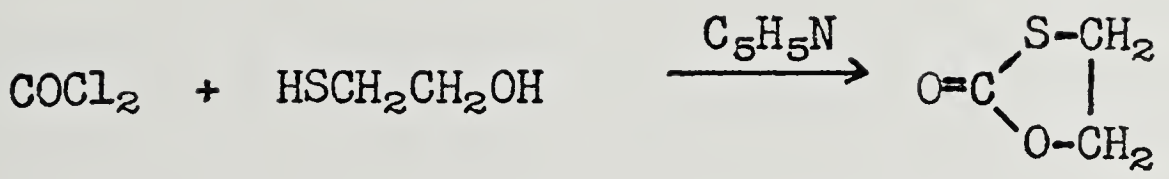
Stevens and Richmond (1941) found that the decomposition of 2,3-butylene glycol monoxanthate followed two paths, one producing methyl ethyl ketone, presumably through the enol, and the other yielding a cyclic thiocarbonate:



In a series of papers Owen and coworkers (Creighton and Owen, 1960; Iqbal and Owen, 1960) have described the preparation of a number of cyclic trithiocarbonates derived from sugars as well as from cycloparaffins. The work herein described is an extension of that work to the preparation of the monothiocarbonates derived from cyclohexane.

Experimental

Ethylene monothiocarbonate can be prepared by Reynold's method (1958) in which a solution of phosgene in ethyl acetate is added to a mixture of mercaptoethanol and pyridine:



A modification of this method was used in the preparation of the two isomeric cyclohexene monothiocarbonates. Starting point for the cis isomer was cyclohexanone. Bedoukian's method (1945) was used to convert it into the enol acetate:

$$C_6H_{10}O + (CH_3CO)_2O \xrightarrow{p\text{-}CH_3C_6H_4SO_3H} C_6H_9OCOCH_3$$

The mixture of cyclohexanone (196 g), acetic anhydride (408 g) and p-toluenesulfonic acid (2 g) was heated for 9 hours under a 10 cm column packed with Lessing rings. The acetic acid was distilled off as formed. The mixture was cooled, 200 ml of water added to decompose unchanged acetic anhydride, the oily layer was washed with water and then with 2N Na_2CO_3 solution. The ester was extracted with ether and dried. Distillation at 29-33° (0.1 mm) gave a yield of about 50%.

Thioacetic acid converted the cyclohexenyl acetate into cis-diacetyl-2-mercaptocyclohexanol:

$$C_6H_9OCOCH_3 + CH_3COSH \rightarrow C_6H_{10}(OCOCH_3)SCOCH_3$$

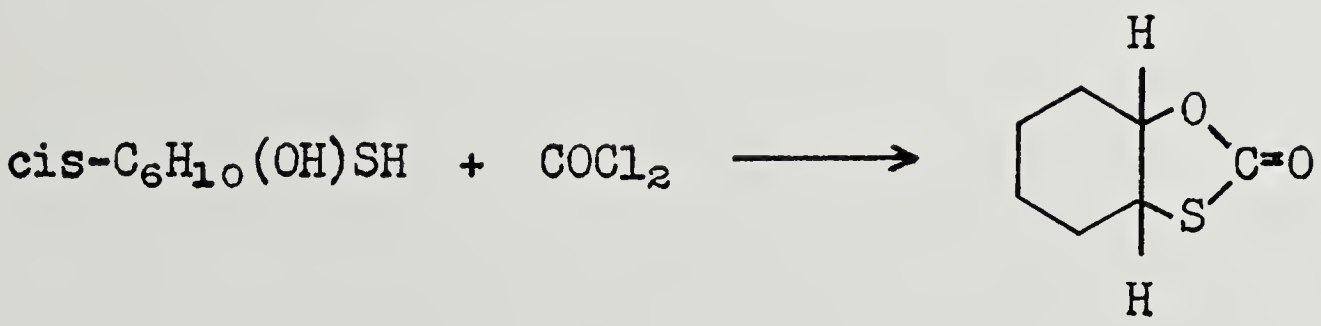
A 25 g portion of the enol acetate was placed in a flask connected to a reflux condenser and 25 g of thioacetic acid and 2.5 g of glacial acetic acid were added. After standing for 2 hours the mixture was heated on the steam bath for 1.5 hours. Fractional distillation at 1.5 mm pressure gave 20 g boiling at 115-118°.

The diester was hydrolyzed to the cis-2-mercaptocyclohexanol by a solution of hydrogen chloride in methanol:

$$C_6H_{10}(OCOCH_3)SCOCH_3 \rightarrow C_6H_{10}(OH)SH$$

Hydrogen chloride gas was passed into methanol until the concentration, as determined by titration with 2N NaOH, was 16.9 g per 100 ml. A 5 g portion of the diester was mixed with 20 ml of methanol and 20 ml of the HCl solution. After standing 5 days the methanol and hydrogen chloride were removed under reduced pressure. The hydroxythiol distilled at 89-91° under a pressure of 8 mm. The yield was 70%.

Condensation of the cis-2-mercaptocyclohexanol with phosgene led to the cis-cyclohexane monothiocarbonate:



In a 100 ml flask were placed 1.6 g of the hydroxythiol, 8 ml of toluene, and 3 g of pyridine. The flask was cooled in an ice bath and 9.75 g of a 12.5% solution of phosgene in toluene added. A white precipitate of pyridine hydrochloride appeared immediately. After 30 minutes a second 9.75 g portion of the phosgene solution was added. At the end of an hour 10 ml of water was added to decompose any excess phosgene. A nitroprusside test for thiol sulfur was negative. The product was extracted with chloroform, washed twice with 25 ml portions of 2N HCl and once with water. After drying the chloroform solution and removing the solvent under reduced pressure, the product was obtained as a colorless oil boiling between 88 and 90° at a pressure of 10^{-4} mm. Analysis: found C = 53.22%, H = 6.40%, S = 20.23%. $C_7H_{10}O_2$ requires C = 53.15%, H = 6.37%, S = 20.26%. U.V. spectrographic data:

$$\epsilon_{\max} = 4187, \lambda = 204.4\text{m}\ \mu$$

The trans isomer was made from cyclohexene which was first converted into the epoxide by the method of Coleman and Johnstone (1941).

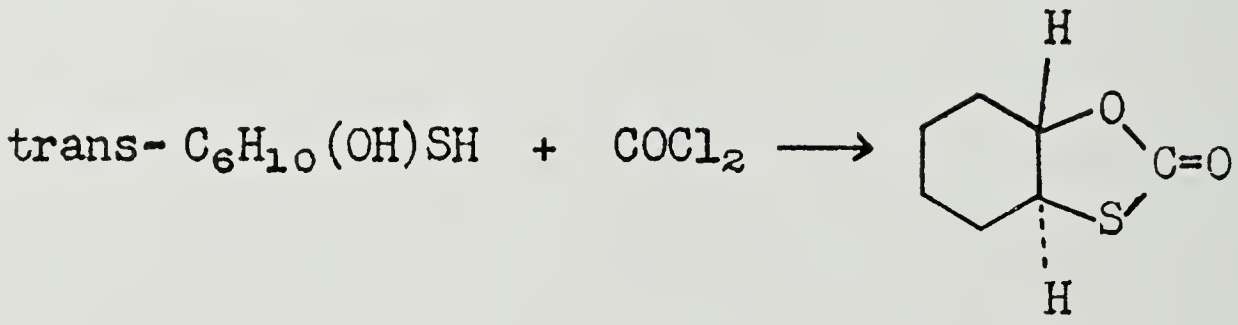
$$C_6H_{10} + HOCl \rightarrow C_6H_{10}(OH)Cl$$
$$C_6H_{10}(OH)Cl + NaOH \rightarrow C_6H_{10}O + NaCl + H_2O$$

Cyclohexane oxide treated with H_2S and KHS led to the trans-2-cyclohexanol:

$$C_6H_{10}O + H_2S \xrightarrow{KHS} C_6H_{10}(OH)SH$$

A solution of 5.6 g of KOH in 40 ml of ethanol was saturated with H_2S while the mixture was kept at 0°C in an ice bath. 9.8 g of cyclohexene oxide was then added to the KSH solution. Hydrogen sulfide was bubbled into the mixture. The temperature rose to 40° due to the heat of the reaction but had returned to room temperature after 30 minutes. Water was added to the pale yellow reaction mixture and the excess KOH was neutralized with 100 ml of N H_2SO_4. H_2S was evolved and a white precipitate appeared which dissolved in excess water. The product was extracted with chloroform and the chloroform solution dried with anhydrous $MgSO_4$. After removal of the chloroform under reduced pressure the product distilled as a viscous water-white liquid at 71-72° (1.5 mm).

The trans-cyclohexane monothiocarbonate was obtained from the trans-2-mercaptocyclohexanol by the use of phosgene:



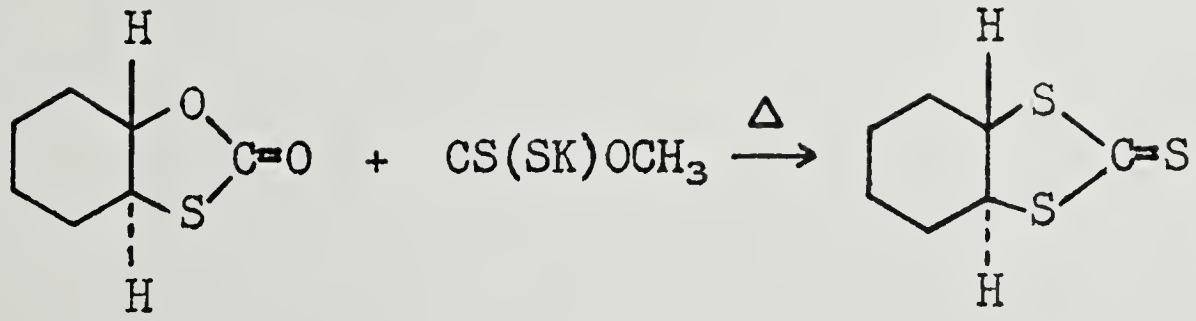
A 2.13 g portion of the hydroxythiol was placed in a 100 ml flask with 4 g of pyridine and 10 ml of toluene. The mixture was cooled in an ice bath and 13 g of a 12.5% solution of phosgene in toluene added. After standing 50 minutes another 13 g portion of the phosgene solution was added. The excess of phosgene was decomposed with 15 ml of water and the product extracted with toluene. The toluene solution was washed twice with 25 ml portions of 2N HCl and once with 25 ml of water. The toluene solution was dried with $MgSO_4$ and the solvent removed under reduced pressure. The product distilled at 80-86° under a pressure of 5×10^{-3} mm. On a second run the material crystallized in the condenser to give colorless needles melting at 27°. Analysis: found C = 53.10%, H = 6.32%, S = 20.25%. $C_7H_{10}O_2S$ requires C = 53.15%, H = 6.37%, S = 20.26%. U.V. spectrographic data: $\epsilon = 8184$, $\lambda_{max} = 203.6$ m μ

The trans isomer is readily converted into the trithiocarbonate by treatment with potassium methyl xanthate (potassium methoxymethanethionothiolate), $CS(SK)OCH_3$, on heating under reflux for 3 hours at 75°C. The yield was 95% of the theoretical. Under similar treatment the cis isomer underwent considerable decomposition but did yield a few small crystals of the bright yellow trithiocarbonate.

Evidence that no inversion occurs during condensation of the mercaptocyclohexanols with phosgene is largely circumstantial. First, trans isomers almost universally melt higher than their cis equivalents. The trans cyclohexanemonothiocarbonate crystallized in the condenser during distillation while the cis form could not be made to crystallize even by cooling in liquid nitrogen or storage in the refrigerator for several days. Second, the study of thermal stability, which will be covered in a later paper, confirmed the belief that the solid isomer was, indeed, the trans form.

Summary

Two new cyclic monothiocarbonates have been prepared from the isomeric 2-mercaptocyclohexanols by treatment with phosgene. The cis isomer is a colorless oil while the trans isomer is a crystalline solid. The trans isomer is easily converted



m.p. 171.5 - 173°

in almost a theoretical yield into the trithiocarbonate by heating with potassium methyl xanthate.

Acknowledgments

The author wishes to express his sincere gratitude to Professor L. N. Owen of Imperial College of Science and Technology, London, for suggesting this problem and for his sustained help and encouragement during the course of the work. Thanks are also due to other members of the department at Armstrong Laboratory, Imperial College, for helpful suggestions, and to the staff members of the analytical laboratory for their careful analyses.

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Manuscript received April 30, 1963.

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EDWIN C. GALBREATH,
Department of Zoology,
Southern Illinois University,
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of the

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Volume 56
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Springfield, Illinois

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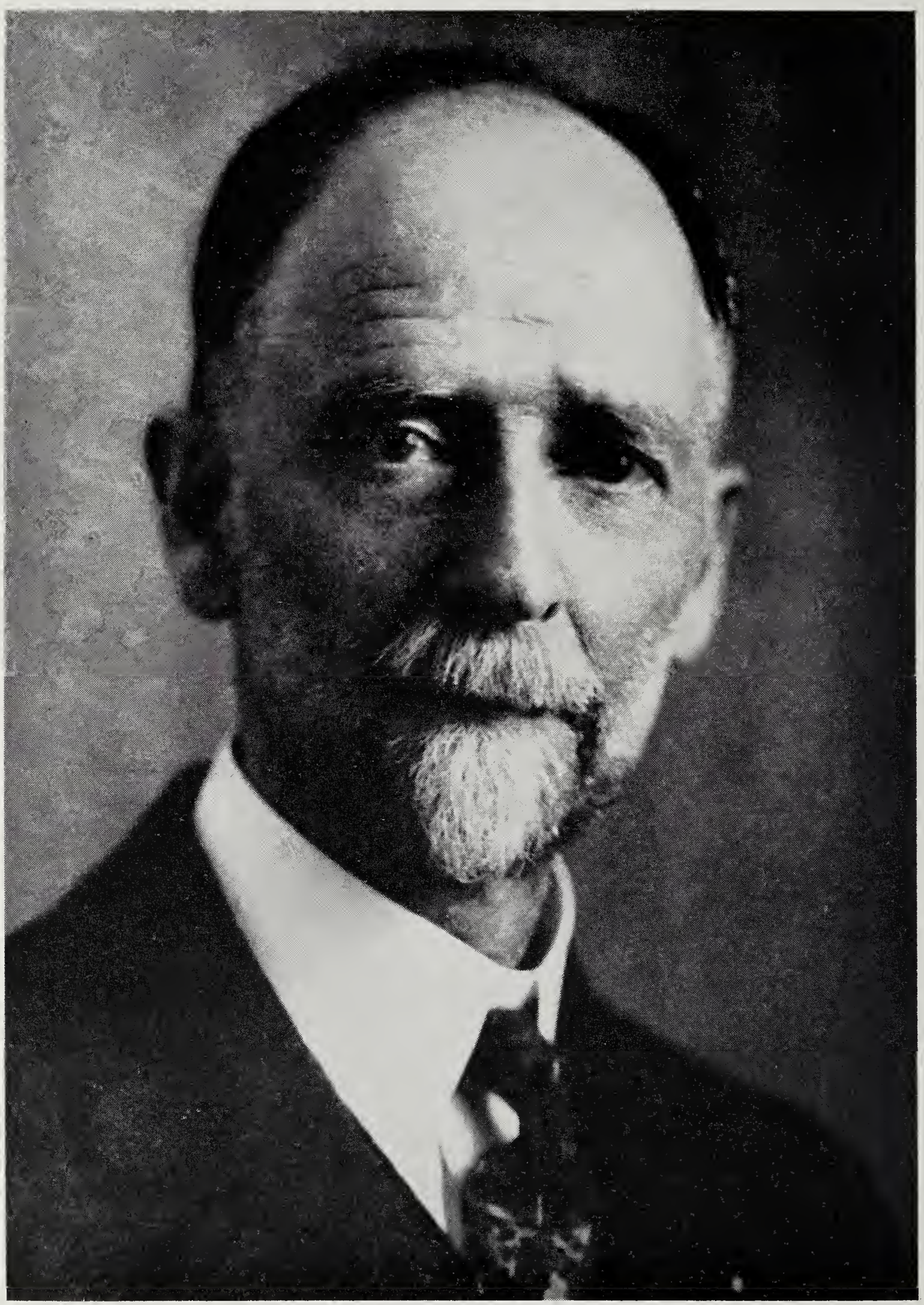


ALJA ROBINSON CROOK

ALJA R. CROOK AND THE FOUNDING OF THE ILLINOIS STATE ACADEMY OF SCIENCE

WALTER B. HENDRICKSON
MacMurrary College, Jacksonville

Editor's note: This article is based, in large part, on the letters of Alja R. Crook in the Director's office of the Illinois State Museum. Because they tell so much about the beginnings of the Illinois State Academy of Science and about the scientific climate of the time, somewhat lengthy excerpts are given. As a supplement to the following account, the reader is referred to an article by Professor William M. Bailey, "The Beginnings of the Illinois State Academy of Science," Transactions of the Illinois State Academy of Science, 1950 43: 24-33. This article is a summary of the proceedings of the organizing meeting, the constitution and bylaws, and the first regular meeting at Decatur in 1908, taken from the now scarce first volume of the Academy's Transactions.

The Background

The Illinois State Academy of Science was founded in 1907. Its predecessor, the State Natural History Society, was disbanded in 1885 because there were too few qualified scientists to provide worthwhile programs at annual meetings. (1)

In the twenty-two years between 1885 and 1907 there was a great increase in scientific activity in Illinois, and the number of scientists became many times larger. Colleges and universities developed departments in the various fields of science and staffed them with Ph.D.'s from the rapidly growing graduate programs of the great universities of the nation, particularly the University of Illinois, the University of Chicago, and Northwestern University. From these centers poured a stream of research papers that were published in the journals of national professional societies. With headquarters at the University of Illinois, the state supported agencies — the Laboratory of Natural History, the Water Survey, and the Geological Survey — explored the natural resources of the state. In cooperation with the United States government, Illinois maintained an Agricultural Experiment Station at the University of Illinois.

Nonprofessional interest in science was also lively. Local science clubs, microscope clubs, and natural history societies were formed in all parts of the state. The courses in natural science in the high schools were being expanded under the direction of young teachers who had majored in this area in college or university. Many of these teachers were working in the summers toward advanced degrees. In Chicago, housed in handsome buildings, were the Field Columbian Museum (later the Field Museum of Natural History and, now, the Chicago Natural History Museum) and the Chicago Academy of Natural Science. The State Museum at Springfield was about to enter upon an expanded program that led, in time, to proper space for popular and educational displays in the Centennial Building.

Such was the scientific mileu into which the Illinois State Academy of Science was projected.

Laying the Groundwork

The key man in founding the Academy was Alja Robinson Crook, a geologist and mineralogist, who had been born in Circleville, Ohio in 1864. He attended Ohio Wesleyan University. After a brief experience in public school teaching, he went abroad for graduate study, earning his doctoral degree at the University of Munich in 1892. In 1893 he became a member of the faculty at Northwestern University and curator of the University museum. In 1906 he moved to Springfield to head the Illinois State Museum of Natural History. (2) He was, therefore, by training and academic background a professional scientist. As a museum director, he was engaged in science education and the popularization of science. (3)

As soon as he took over his new post, Dr. Crook realized that a state organization of scientists would be desirable. He knew that academies of science were flourishing in the neighboring states of Indiana, Iowa, and Michigan and felt that the time was ripe to establish an academy in Illinois. He wanted the support of Illinois scientists in his drive to expand the State Museum. (4) In Springfield, where there was no college or university, he missed his contacts with his fellow scientists in the Chicago area, and he decided to bring them to him at Springfield. (5) Above all, he wished to promote the interests of science in Illinois. For these reasons he set about the organization of a state academy of science.

In February, 1907, Crook sent a letter to some of the leading university teachers of science, enclosing a draft of a circular which he proposed to send to high school and college teachers, school district superintendents, principals of high schools, members of the Chicago Academy of Science, and others who might possibly become members of a state academy. As he said to Henry Crew, Professor of Physics at Northwestern and his personal friend,

> As you know, it [the academy] cannot be successful unless the leaders of science in the state give it their hearty support. Unfortunately while the college men are most necessary to the organization they probably feel the need of it least, yet I hope that they, with their customary altruism may take up the movement so that we can not only get numbers but also leaders of science in the State. (6)

Crook also sent a copy of his proposed circular to H. Foster Bain, the head of the State Geological Survey, for his suggestions. Bain made some comments, and heartily approved the whole idea. (7) Other men to whom Crook wrote were equally enthusiastic. Crook next sent a general letter to all college and university teachers. This letter is of interest because it is the first formulation of the aims of the Academy, and it shows clearly Crook's influence on the form taken by the Illinois State Academy of Science:

> There seems to be a somewhat general demand in Illinois for the organization of a State Academy of Science similar to those that exist in our neighboring States. The purpose of such an Academy would be to increase interest in Science and

> to promote the interest in science by banding together all grades of scientific workers.
>
> The Academy would furnish a means of extending the acquaintance of scientific men of the State among themselves. It would afford a stimulus to beginners and workers in science in the more isolated communities in the State. It would be the means of encouraging research and publication. It would aid in the dissemination of scientific knowledge. Its influence would promote the efficiency of the scientific work done by the State. (8)

More than a hundred persons responded to this appeal (9); over forty signatures being obtained from the men associated with the University and other agencies at Urbana-Champaign. (10) The members of the Science Club of Northwestern University agreed to support the proposed Academy. (11) Timothy C. Chamberlin, the eminent geologist of the University of Chicago, who was associated with the Carnegie Institution where he was engaged in the study of fundamental problems of geology, expressed the general reaction of university teachers when he said,

> I am embarrassed because I am so delinquent about fulfilling obligations to societies with which I am already affiliated, but none the less I realize that the movement for a State Academy is supported by strong reasons that lie outside those of any existing organization, and if you will accept what little help I can give you under the circumstances I shall not only be willing but grateful for the opportunity to help. (12)

Assured of the backing of the most prominent scientists in the state, Crook sent out over 600 circulars in October, 1907 in which he restated the objectives of the proposed academy, and announced that an organization meeting would be held in Springfield in the Senate chamber of the Capitol on December 7. (13) This date, somewhat closer to the Christmas holidays than Crook liked, was necessary because the last weekend in November had been taken by a meeting of science and mathematics teachers in St. Louis. (14) A number of interested persons wrote to Crook stating that they could not attend, but asked to be enrolled as members. (15)

Having secured the best possible date, Crook went about the preparation of a program. He wrote to Stephen A. Forbes, State Entomologist and Director of the State Laboratory of Natural History, saying that he proposed a one day meeting, opening with a short talk by Chamberlin on the advantages of a State Academy of Science. Crook asked Forbes to talk on the history of earlier science organizations in Illinois. There was to be, also, a symposium on opportunities in various branches of science. In the evening there would be a public lecture by W J McGee, a nationally known spokesman for science. (16)

As a last minute device for securing attendance at the Springfield meeting, Crook wrote to the presidents of colleges and universities and other influential people in the state. The burden of his plea, as set forth in his letter to Abram W. Harris, the president of Northwestern University, was:

> For the advancement of science in the State, for the sake of Northwestern University and for the interests of the men themselves, I hope the majority of the scientific members of your faculty will find it possible to attend the organization meeting of the State Academy of Science on December 7.

I offered two members of the faculty places on the program, but they were unable to come. Being surrounded with men of science, University men often feel but slightly the great need which isolated workers have for encouragement and stimulation. They appreciate the need least but are most necessary to supply that need.

If your men can come here and assist the organization they will be doing work which will extend their own influence and that of the University more than they can imagine. There is some danger that men of less attainments may predominate at the meeting and give it a wrong start. The first meeting is of the greatest importance. Cannot the Northwestern men come down in a body and see that this whole affair is given such an impetus as to markedly influence science and education throughout the whole state?

They could leave Chicago at 11:45 Friday night, spend Saturday at the meeting and return Saturday night. Since the 2 cent fare has gone into effect the expense is not great. They will be carrying their influence right down into the heart of the state. (17)

The Springfield Meeting

Crook's last minute panic ended when he saw more than a hundred persons in the Senate chamber on Saturday morning, December 7, 1907. (18) He had bagged the biggest men in Illinois science as participants. Greetings were extended by James A. Rose, the Secretary of State, on behalf of Governor Charles S. Deneen. Professor Ulysses Sherman Grant, head of the Geology Department at Northwestern University, was elected temporary chairman.

Appointed to a committee to submit a constitution were John G. Coulter, a botanist at Illinois State Normal University, who had recently returned from the Phillipines where he had assisted in setting up a public school system; William A. Noyes, chemist, University of Chicago, and editor of the recently established *Chemical Abstracts;* H. Foster Bain, head of the Illinois State Geological Survey, and later to be head of the United States Bureau of Mines; Henry Crew, physicist, Northwestern University, and associate editor of the *Astrophysical Journal;* Herbert V. Neal, biologist, Knox College, and later director of the Barnum Museum of Tufts College; Samuel W. Williston, University of Chicago, vertebrate paleontologist and prolific writer on biological and educational subjects; Charles B. Atwell, botanist, Northwestern University; F. L. Charles, Northern Illinois Normal School; and B. B. James, Millikin University. Forbes and Chamberlin were also on the committee. Later, when officers were elected, Chamberlin became president; Crew, vice-president; Crook, secretary; and John C. Hessler, chemist and future president of Knox College, treasurer. These officers along with Forbes, Thomas W. Galloway, biologist, Millikin University, and John P. Magnuson, chemist, Augustana College, made up the Council of the Academy. (19)

After the Secretary of State had spoken, Professor Chamberlin made the key-note address: "The Advantages of a State Academy of Science." He said that, in an age of specialization, scientists had little community of interest, that there was "a great lack of appreciation of other fields than that of their own." He pointed out, also, that a state academy would benefit young scientists, amateurs, isolated scientists,

and workers in scientific centers, and that at its meetings members would receive mutual stimulation. Further, he said, an academy would be an effective means of disseminating an appreciation of the spirit and method of science to the legislature and advising that body on scientific matters. Chamberlin ended his talk by a statement of a point of view held by some scientists of the early twentieth century. In the new power and confidence felt by science as a result of the great progress in the preceding half-century, and the potentiality for even greater things to come, Chamberlin declared:

> The spirit and method of science is valuable to the state and nation as an essential element in the solution of its great social, political and ethical problems. The habit of conscientious search for the precise truth and the systematic control and guidance of the opinion and action in accordance with the canons of scientific procedure [are] a means of supreme value in the elevation and purification of the common thought and feeling of the people. More than anything else, are the intellectual and moral methods of science a protection against current evils and a guarantee of safety in the future. (20)

It is probably fortunate that Chamberlin's pronouncements were not implemented by the Academy, but that the aims and purposes followed the more modest course outline by Crook. The Academy has never set itself up as the defender of morals or the protector of society.

Forbes followed Chamberlin at the rostrum, speaking about former natural history societies of Illinois and saying that "the history of scientific organizations is a part merely of the history of scientific progress of civilization, and especially of education." He declared that "the present interest here is in examining the past as a guide to how to make the present organization a success."

Forbes was especially well qualified to speak on his topic because he had been associated with organized science since 1872 when he came to Illinois State Normal University to head the museum which the state had inherited from the Illinois Natural History Society when that organization, founded in 1858, went out of existence. Forbes had also been associated with the two predecessors of the Illinois State Academy of Science, the High School and College Association of Natural History (1877-78) and the State Natural History Society (1879-1885). He pointed out that most scientists of the 1870's and 1880's were amateurs and said, "We have more specialists here today from one department of one institution than there were in our whole membership in 1879 . . . And I hardly need say that, after the lapse of twenty-two years of amazing progress in science and science education an entirely new situation exists in Illinois — one so radically different . . . that the conclusions then reached have no bearing on our problem today." (21)

Forbes stated that these earlier organizations failed because there were too few professionals, and because they had not made a permanent record by publishing their transactions. A look at the present success of the Illinois State Academy of Science makes it clear that Crook and his associates, by enlisting the support of the professional scientists and by immediately

starting the publication of the Academy's Transactions, profited by the experiences of the early societies.

After these addresses, and while the committee to prepare a constitution was meeting, the other members discussed the aims of the proposed academy. Many ideas were considered, several of them finding places later in the operations of the Academy. For example, Dr. C. E. M. Fisher thought it desirable that the Academy affiliate with other organizations with similar objectives. Clarence W. Andrew of the John Crerar Library suggested that libraries should be members. Thomas J. Burrill of the University of Illinois thought that it would be better to use the word "science" rather than "sciences" in the name of the Academy. Isabel Smith of Illinois College would look to the Academy for influence on the conservation of forests. Henry Crew advised against too small sections, and suggested that there be just two, either natural and physical or pure and applied. Albert Carver of Springfield High School wanted all meetings held at Springfield because of its central location, while Edgar J. Townsend of the University of Illinois advocated that the meetings be alternately out in the state and in the capital. (22)

In the midst of this discussion the committee on the constitution reported. Although there is no mention of it, certainly the committee worked from an already prepared draft, otherwise it would not have been able to report after such a brief meeting. It is very likely that Crook, with his fine sense of how to get things done, had such a draft ready to hand to the committee.

The constitution was a short document. It declared that the object of the Illinois State Academy of Science would be "the promotion of scientific research and scientific spirit, and the unification of the scientific interests of the state." Active, corresponding, life, and honorary memberships were provided for, the first class paying a one dollar initiation fee and annual dues of one dollar. Life memberships were 20 dollars. Election to any class was through proposal by two members and approval by the majority of the membership committee. All those present at the organizing meeting were declared to be charter members. There were to be the usual officers, and they, with the immediate past-president and the chairmen of sections (just what sections there should be was not stated) made up the Council which was to manage affairs between annual meetings. Two standing committees — publication and membership — were set up, the former responsible for editing and publishing the *Transactions* which were to be distributed to members without cost.

This necessary business taken care of, the rest of the day was given over to a program. In the afternoon there was a symposium: "The Outlook for Young Men in Various Sciences." It is not clear why this subject was chosen, since there were not many present who were not already established as teachers and researchers. It may be that Crook thought that such a subject would be a means of getting the big men

in science to appear on the program. He was able to appeal to their sense of responsibility to advance science, and yet did not require that they spend much time in preparation. It is also possible that he saw the symposium, as it would be reported in the press, as a means of getting across to the public the idea that science was useful.

Whatever the reasons, the speakers on anthropology, botany, chemistry, geology, physics, and zoology demonstrated that science offered an opportunity for young men to derive personal satisfaction, as well as render public service, through careers as teachers or as researchers in either government or private employment. The speakers declared that the demand for qualified scientists far exceeded the supply. They pointed out that it was necessary for a man to earn a graduate degree to get ahead in any area of science. Some special opportunities were mentioned. W J McGee, for example, declared that anthropology, a comparatively new branch of science, still have not solved such primary problems as classification, correlation, or serial development and its relation to human life. Calling on his recent experience as an educator in the Phillipines, John G. Coulter said that there was a special need for botanists. He echoed a theme running through all the natural sciences, but especially botany, that there was need for ecological studies. Coulter's remarks foreshadowed what came to be a continuing interest of the Academy in the teaching of science when he said,

> No where in our educational literature is the absence of clean truth more conspicuous than in nature-study books which are in common use in the graded schools. No where has the unauthorized word had a wider play or more credulous following. Untrained teachers have had nature thrust upon them and have turned with avidity toward whatever seemed to offer help. Composites of sentiment and inaccuracy have been liberally supplied as 'supplementary reading.'

Coulter suggested that the academy undertake the publication of a series of papers on science topics, especially concerning Illinois, even though some felt this was too big an undertaking for the new organization. (23) Professor Noyes noted that "the amount of knowledge which has been accumulated in chemical science is so great that I feel safe in saying that the detailed knowledge of this science [chemistry] is greater than the whole mass of knowledge of all the sciences fifty years ago." He went on to say that there were more than 8,000 chemists in the United States, thirty of them at the University of Illinois. (24)

The organizational meeting of the Illinois State Academy of Science was brought to a close by a dinner, after which W J McGee spoke to an audience of more than 600 persons on the subject, "Greater Steps in Human Progress." There is no record of what he said.

Dr. Crook, who had been circulating among those present, signing up members and collecting dues, was well satisfied with the success of his carefully planned project. He said, "The interest which was displayed throughout the meeting argues [*sic*] well for a successful and useful career for the society."

Notes and Literature Cited

1. See Walter B. Hendrickson, "The Forerunners of the Illinois State Academy of Science," in Illinois State Academy of Science, Trans. 56 (1963), 105-128. Cited hereafter as ISAS, *Trans.*
2. Henry C. Cowles, "Alja R. Crook, 1864-1930," ISAS, *Trans.*, XXIV (1931), 31.
3. A. R. Crook, *Report of the Illinois State Museum of Natural History at Springfield, Illinois*, January, 1907 (Springfield, 1907), 7-8.
4. *Ibid.*, 7-11.
5. Charles C. Adams, University of Chicago, to Crook, Sept. 9, 1907. Illinois State Academy of Science Letter File 1907-11, in Director's Office, Illinois State Museum. Cited hereafter as ISAS File 1907-11.
6. Rough Draft, Crook to Crew, Springfield, n. d. (early 1907), ISAS File 1907-11.
7. Crook to Bain, Springfield, Feb. 11, 1907 and rough draft of circular, ISAS File 1907-11.
8. ISAS File 1907-11.
9. Printed circular addressed to "Men of Science in Illinois." ISAS File 1907-11.
10. H. F. Bain to Crook, Champaign, April 11, 1907, enclosing list of names, ISAS File 1907-11.
11. E. H. Harper, Evanston, Apr. 9, 1907. ISAS File 1907-11. Many other letters in answer to Crook's circular are in the same file.
12. Chamberlin to Crook, Apr. 16, 1907. ISAS File 1907-11.
13. Printed copy in ISAS File 1907-11.
14. Charles C. Adams to Crook, Chicago, Oct. 4, 1907, ISAS File 1907-11.
15. See Letters from Charles B. Atwell and others to Crook, ISAS File 1907.
16. Crook to Forbes, Springfield, Nov. 2, 1907, carbon copy, ISAS File 1907-11.
17. Crook to Harris, Springfield, Nov. 14, 1907; R. J. Carmichael, District Passenger Agent, Illinois Central Railroad to T. C. Chamberlin, Nov. 23, 1907, carbon copy, ISAS File 1907-11.
18. The proceedings of the organizing meeting are in ISAS *Trans.*, I.
19. Sources for the identification of persons were the appropriate volumes of *American Men of Science*, *Who's Who in America*, *Who Was Who in America*, and lists of members in the early volumes of ISAS, *Trans.*
20. ISAS, *Trans.*, I, 15-17, *passim.*
21. *Ibid.*, 18-29. See also reference 1 of this article.
22. *Ibid.*, 6-7.

Manuscript received August 13, 1963.

PRECIPITATION IN A 550-SQUARE-MILE AREA OF SOUTHERN ILLINOIS

STANLEY A. CHANGNON, JR.
Illinois State Water Survey, Urbana

Since October 1957 the Illinois State Water Survey has operated a dense raingage network in southern Illinois, one of four networks within the state, to obtain accurate and detailed precipitation data for use in water resources research programs. This southern network, called the Little Egypt Raingage Network, provides a precipitation sampling area of 550 square miles in which there is one gage in each 11 square miles.

Precipitation data from this densely gaged network have provided information pertinent to three interrelated types of study in Southern Illinois. For climatological studies concerning the long-term averages and extremes of weather, information was obtained on the spatial variability of monthly, seasonal, and annual precipitation.

Knowledge of general meteorological interest concerning the physical atmosphere was obtained also, particularly data on time of precipitation formation, location of precipitation initiation, and duration of precipitation periods. Of primary interest to the Water Survey was the hydrometeorological information directly applicable to engineering problems in water resources, and particularly the information on characteristics of excessively heavy rainstorms in southern Illinois.

Selected findings for these types of studies from the network precipitation data for the 1958-1962 period are presented. Although a five-year period may not be adequate to provide a representative measure of some of the precipitation characteristics discussed, it can provide useful approximations, and this study gives a measure of what a five-year sample of precipitation can yield.

Network Area Description

The distribution of the 49 network raingages is portrayed in Figure 1. Every effort was made to place the raingages in a strict geometric pattern with a distance of 3.2 miles between gages. Great attention was given to the selection of sites with equivalent exposures. The network contains 25 standard 8-inch weighing-bucket recording raingages, which are serviced by a trained technician, and 24 standard 8-inch nonrecording (stick) raingages which are serviced by volunteer observers. The recording and nonrecording raingages generally were alternated for statistical purposes.

The network lies in the Mt. Vernon Hill Country Physiographic Section (Leighton et al. 1948), and the center of the network is located about 90 miles southeast of St. Louis (Fig.

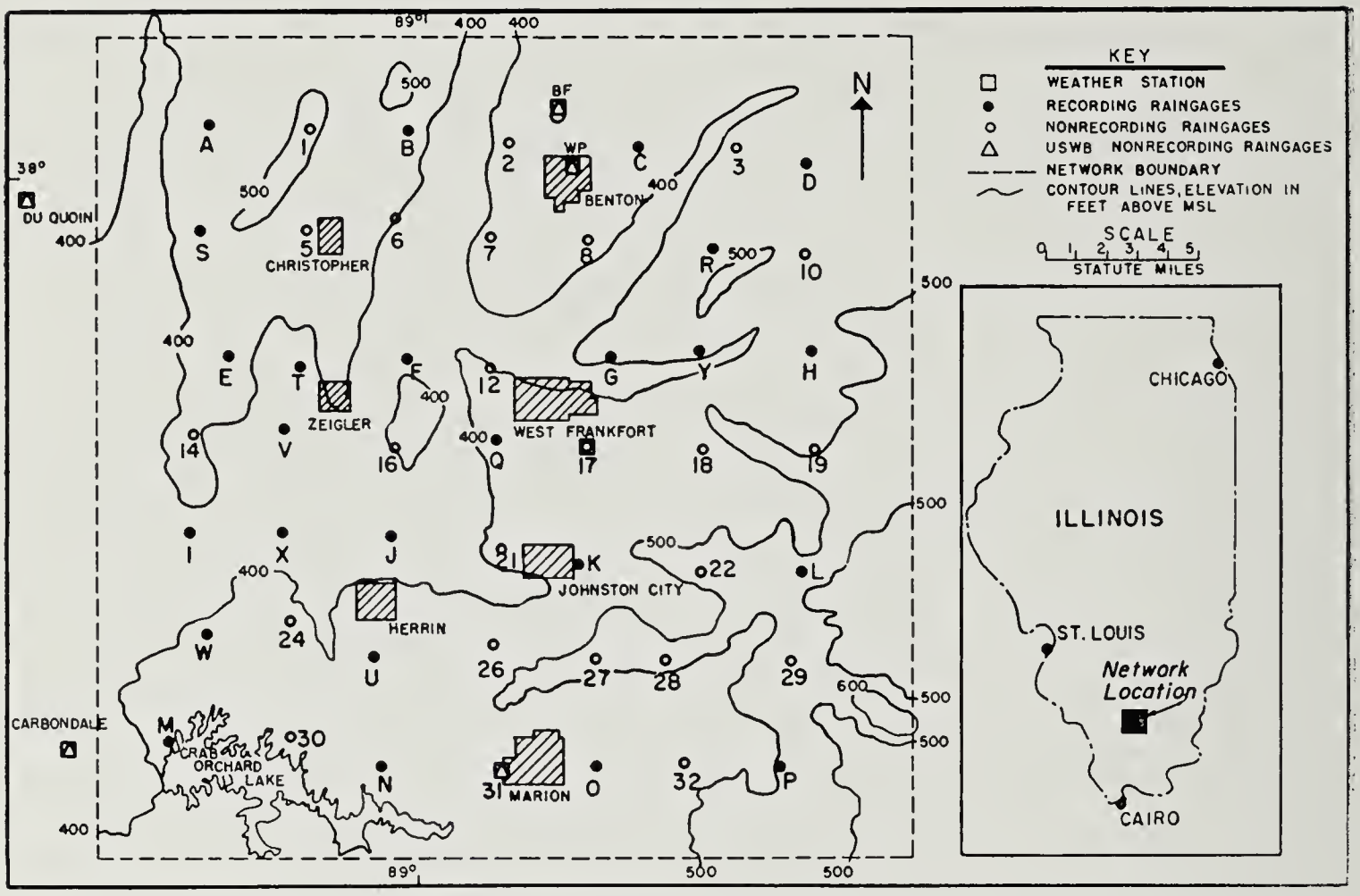


FIGURE 1.—The Little Egypt Raingage Network in Southern Illinois showing 49 gages within a square area of 550 square miles. Positions and types of raingages, elevation contour lines, and urban communities of the area are denoted.

1). The topography of the land is generally flat with a few low hills and ridges located in the eastern and northern parts of the network. The total relief is 250 feet, and elevations range from 350 feet (MSL) in the western part to 600 feet in the southeastern corner. Most of the area enclosed by the network boundary is a part of the drainage basin of the Big Muddy River.

The network is located in the center of the southern Illinois coal mining area which is referred to as Little Egypt (Price, 1958). A study of the land use in the network area revealed that 55 percent of the surface area is cropland, 18 percent woodland, 12 percent pasture land, 9 percent waste land, 4 percent urban areas, and 2 percent is bodies of water.

ANALYTICAL METHODS

The basic analyses were based upon data for distinct periods of precipitation occurrence in the network. These periods of precipitation were delineated from a subjective definition. Any period of precipitation in the network which was separated in time from other precipitation by more than a six hour span of time without precipitation was identified as a precipitation period. Such a separation is believed to be adequate for separating most precipitation occurrences associated with different or separate meteorological conditions. For simplicity, all such precipitation periods were labeled as "storms" and are so referred to hereafter in this report. Obviously, more than one storm

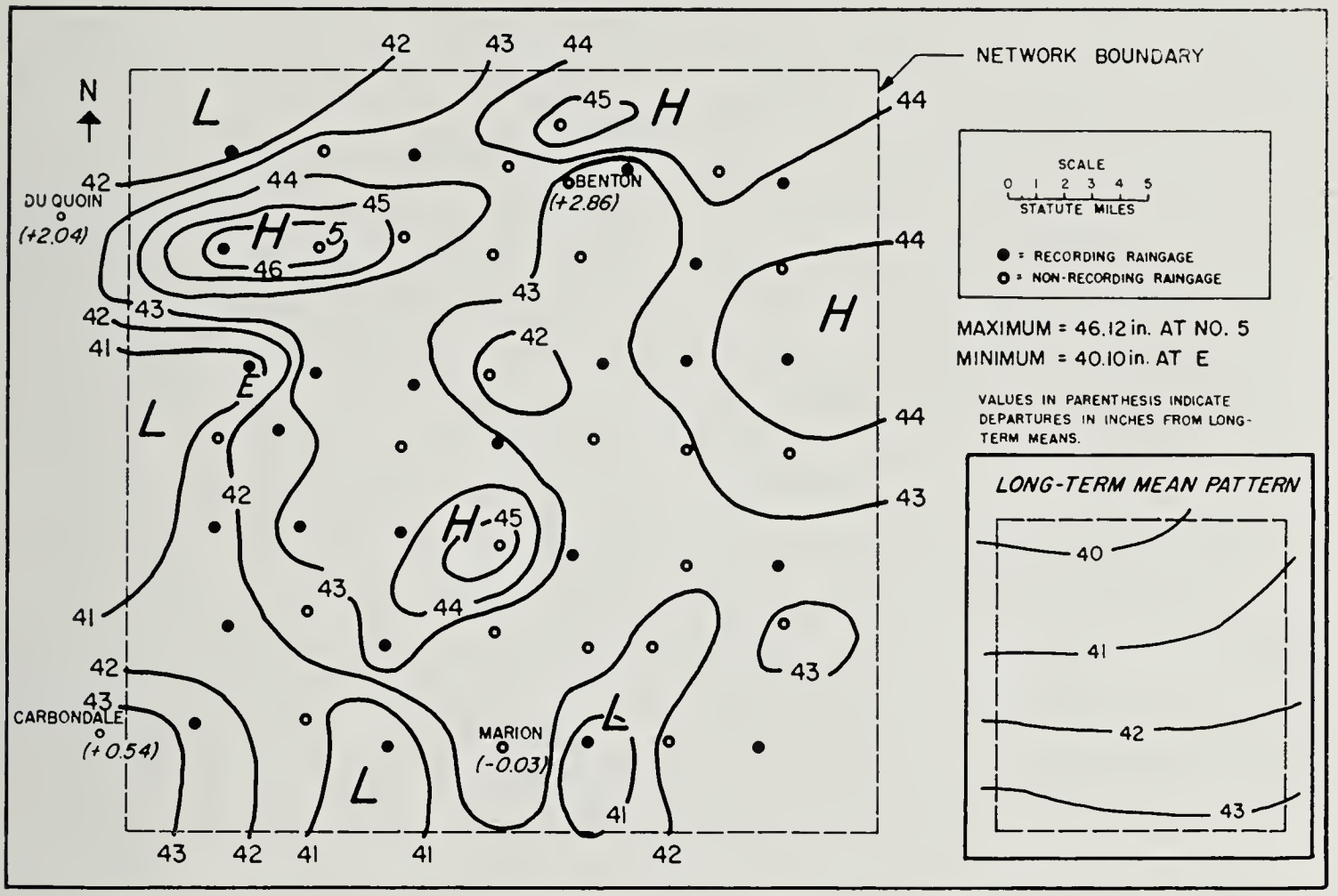


FIGURE 2.—Isohyetal pattern based on network average annual precipitation values (in inches) during 1958-1962 indicates the great areal variation detectable from dense network data. Note that average five-year pattern reverses the north-to-south increase seen in the long-term mean precipitation pattern.

would and did occur in a single calendar day, and many storms contained two or more "bursts" of heavy rain separated by short intervening periods of either lower rainfall rates or no rain.

For each storm, an isohyetal map of the network was prepared and the mean amount of precipitation over the network was calculated by averaging all gaged amounts. In addition, the average duration of the storm at any point in the network was calculated, and the time and location of the beginning and ending of the storm and the precipitation type were listed.

CLIMATOLOGICAL FINDINGS

Annual Precipitation. Figure 2 shows the average annual precipitation pattern in the network; the annual mean for the five-year period was 42.93 inches. The greatest average annual point value was 46.12 inches at gage 5, and the lowest value was 40.10 inches at gage E. Thus, a spatial variation of more than 6 inches, or 12 percent, occurred across a five-mile distance. Changnon (1962) noted similar short-distance variations in average annual precipitation values for ten-year periods in dense raingage networks in central Illinois. In general, pre-

cipitation was least in the southern part and greatest in the northern and eastern parts.

Also shown in Figure 2 is a small-scale inset map of the network area which portrays the pattern of precipitation for the area based on long-term annual normals of the U. S. Weather Bureau (1956). The mean pattern has a south-to-north decrease which is the reverse of the 1958-62 average pattern. Comparison of the pattern on this inset map with the 1958-62 pattern furnishes some measure of the great amount of areal variation in average annual amounts which are detected by a dense network of raingages.

Four Weather Bureau stations in the immediate vicinity of the network had long-term normal values and the departures of the 1958-62 annual average amounts from these normals are shown in parenthesis for these four stations (Fig. 2). The 1958-62 annual averages at Du-Quoin and Benton were 2 to 3 inches in excess of their long-term normals, whereas those at Marion and Carbondale were near normal. The precipitation during the 1958-62 period in the network area can be classified as near to slightly above normal.

Comparison of the five-year average annual values shown on Figure 2 with surface elevation (Fig. 1) revealed a lack of correlation. This comparison was made to discern whether or not locations in the network with higher elevations experienced higher precipitation amounts. Such a relationship has been found in the Shawnee Hill area located south of the network (Roberts et al., 1957). The possible relationship of precipitation and elevation was investigated by sorting the 1958-62 values of all 49 raingages according to the raingage elevations. As shown in Table 1, there was no discernible relationship since the raingages located in the two highest 50-foot elevation intervals produced relatively low average annual values, and the highest interval value came from raingages located in the middle elevation range.

TABLE 1.—Average Annual Precipitation Values for Fifty-foot Intervals of Elevation in the Little Egypt Network.

Elevation interval, feet above MSL	Number of raingages	Average value rainfall (in.) per interval
351-400	12	43.01
401-450	18	42.77
451-500	10	43.33
501-550	6	42.70
551-600	3	42.98

The relationship of the average annual precipitation pattern with other data which might explain the distribution was further investigated. A count was made of the number of times each raingage received the maximum amount of precipitation in a storm. These data showed very little correlation with the amount of precipitation. For instance, gage P (Fig. 1) received the greatest number of storm-maximum amounts, a total of 36, and yet gage P had a relatively low average annual value. A similar inverse relationship occurred at gage A which had the second greatest number of storm-maximum values, 30, but a low annual precipitation value.

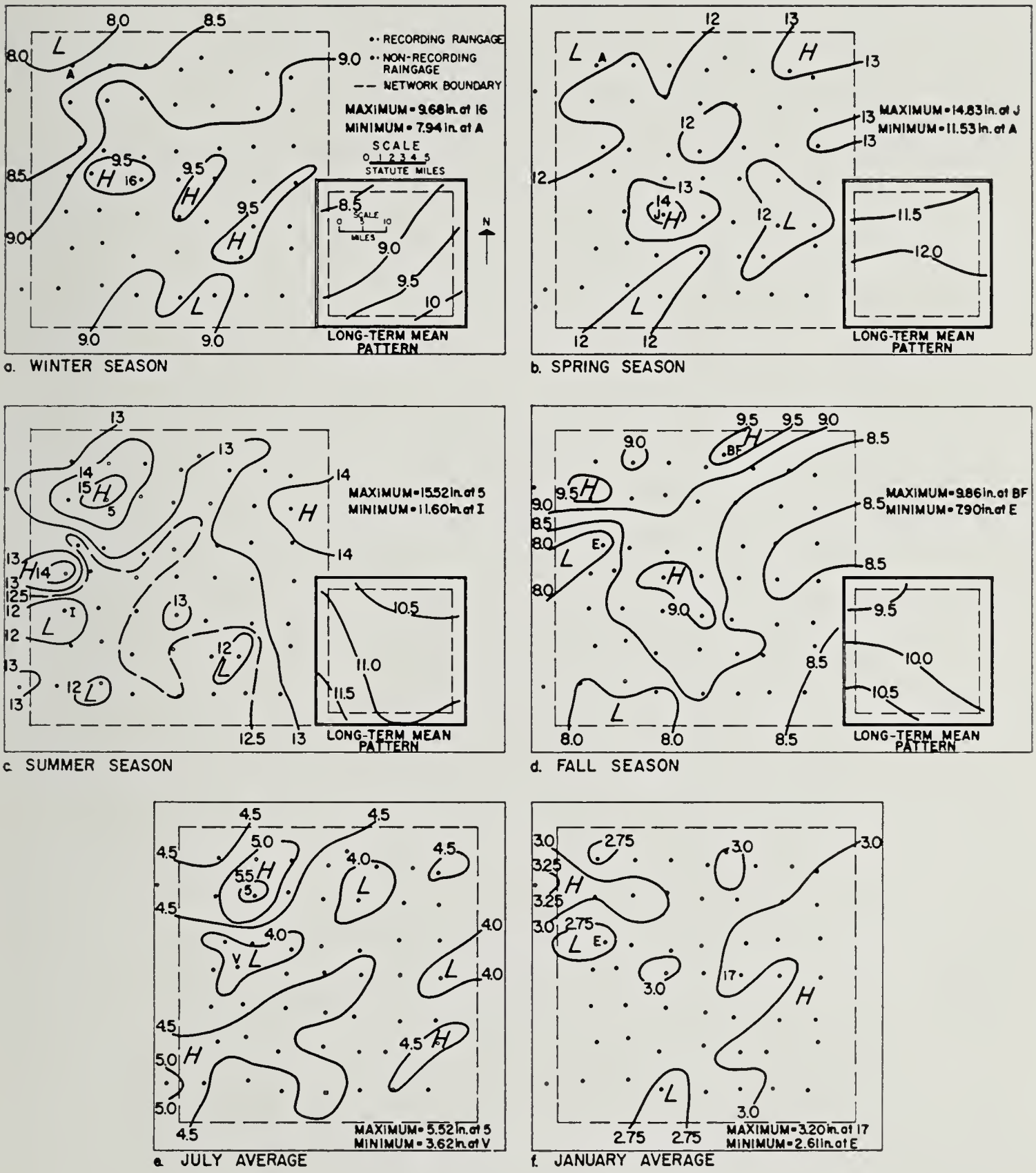

•• RECORDING RAINGAGE
•• NON-RECORDING RAINGAGE
— — NETWORK BOUNDARY
MAXIMUM = 9.68 in. at 16
MINIMUM = 7.94 in. at A
SCALE
0 1 2 3 4 5
STATUTE MILES
LONG-TERM MEAN PATTERN
a. WINTER SEASON
MAXIMUM = 14.83 in. at J
MINIMUM = 11.53 in. at A
LONG-TERM MEAN PATTERN
b. SPRING SEASON
MAXIMUM = 15.52 in. at 5
MINIMUM = 11.60 in. at I
LONG-TERM MEAN PATTERN
c. SUMMER SEASON
MAXIMUM = 9.86 in. at BF
MINIMUM = 7.90 in. at E
LONG-TERM MEAN PATTERN
d. FALL SEASON
MAXIMUM = 5.52 in. at 5
MINIMUM = 3.62 in. at V
e. JULY AVERAGE
MAXIMUM = 3.20 in. at 17
MINIMUM = 2.61 in. at E
f. JANUARY AVERAGE

FIGURE 3.—Seasonal and selected monthly isohyetal patterns for the Little Egypt Network based on average preciptation values (in inches) for the study period. The greater warmer weather variability is clearly portrayed in these patterns.

The number of times each recording raingage received a 30-minute to 24-hour rainfall value equal to or in excess of the two-year frequency value was also compared with average annual precipitation at the 24 recording raingages. The areal pattern of these excessive rainfall occurrences is shown in Figure 10, and is discussed more fully under Hydrometeorological Findings, page 183. A correlation coefficient of +0.65 was

obtained for the average annual amounts and the total number of excessive rainstorms. This coefficient indicated that the storms with excessive rainfall values, which occurred primarily in the warm seasons, explained about 40 percent of the areal variation found in the average annual precipitation in the network.

Seasonal Precipitation. Maps of the average seasonal precipitation for the 1958-62 period are presented in Figure 3. For each season a small inset map has been included to show the mean seasonal precipitation pattern based on long-term normals for stations in the network area.

The winter season precipitation pattern (Fig. 3a) has a relatively flat gradient with a general increase from the northwest to the southeast which is similar to the long-term mean precipitation pattern. The magnitude of the five-year average values is also approximately equivalent to those based on long-term means for the area. The spring pattern (Fig. 3b) has considerably more areal variations than does the winter pattern. The average spring values varied from a low of 11.5 inches at gage A to a high of 14.8 inches at gage J, a 3.3-inch difference. Most of the network had five-year average values equal to or greater than the long-term mean values indicated for spring.

The precipitation pattern of the summer season (Fig. 3c) has greater areal variability than that of the other three seasons. Precipitation in summer was greatest in the northwestern parts where gage 5 had an average of 15.5 inches. Precipitation was least in the southwest where gage I had 11.6 inches, making a maximum difference of nearly 4.0 inches. The low averages in the southwest are in direct contrast with the long-term pattern. The entire raingage network had average summer values in excess of the long-term mean values.

The fall season pattern (Fig. 3d) also exhibited considerable areal variability within the network. As in the summer season, the highest averages occurred in the northern parts which again is in direct contrast to the pattern based on long-term means. The 9.5-inch averages for 1958-62 were the only near-normal values in the network, and all other fall values in the network were below the long-term means.

Thus, in relation to the magnitude of precipitation, the five-year precipitation values for the spring and summer seasons were greater than long-term mean values. Those in the winter season were near normal, and those in the fall season were generally below normal. The winter precipitation pattern for the 1958-62 period was quite similar to the long-term mean pattern for winter. However, the five-year precipitation patterns for the spring, summer, and fall seasons exhibited considerably more areal variability than did the long-term mean patterns for these seasons.

Monthly Precipitation. The precipitation patterns for two months are shown in Figure 3 to illustrate the areal variability in monthly patterns based on five-year averages. Considerable point-to-point variation is shown in the July pattern (Fig. 3e) which has a maximum difference of nearly two inches between gages

TABLE 2.—Precipitation Conditions in Little Egypt Raingage Network.

	Winter	Spring	Summer	Fall	Annual
Average number of days with precipitation in network.....	32	41	45	32	150
Average number of storms with network mean rainfall of					
trace or more.....	23	37	50	30	140
0.25 inch or more.....	11	16	14	8	49
0.50 inch or more.....	6	9	7	5	27
1.0 inch or more.....	2	3	3	3	11
Average number of storms with					
thunderstorms	3	18	35	12	68
hail	1–	6	2	1–	9
excessive rainfall values.....	1–	4–	8	2	14
Average duration at a point, hours, for					
all storms.....	11.6	6.4	2.6	5.2	5.5
storms with network means of 0.5 inch or more.....	18.3	11.9	7.2	12.6	12.3
Percent of total time with rain....	12	11	6	7	9

V and 5 which are six miles apart. The January average pattern (Fig. 3f) exhibits much less areal variability of precipitation, but moderate variations in short distances are shown in the area near gage E.

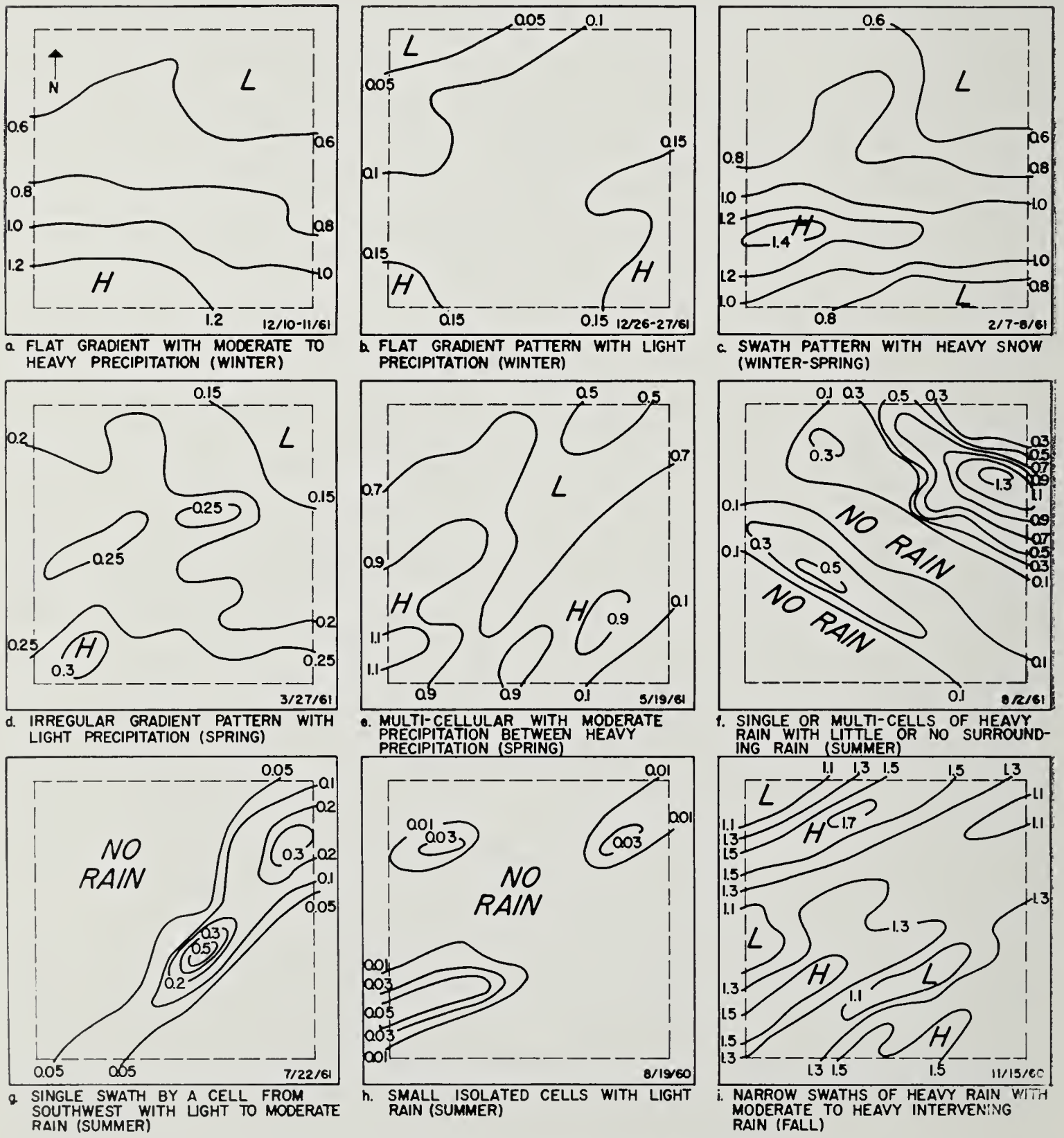
Frequencies of Storms, Days with Rain, and Associated Weather Conditions. Among the climatological data derived from the network precipitation records were various network frequencies for calendar days with precipitation, for storms with varying network mean precipitation amounts, and for different weather conditions associated with the storms. Averages for much of this data are summarized in Table 2. In general, there were fewer storms than days with precipitation because some storm periods overlapped into two or three days. However, in the summer season there were more storms than days with rain because many summer storms were short and occasionally two occurred on the same calendar day.

During the 1958-62 period a total of 702 storms occurred, which is an average of 140 per year. Storms occurred most frequently in the summer and least frequently in winter. Nearly 50 percent of the total storms in winter and in spring had network mean precipitation values of 0.25 inch or more, but only 25 percent of the total storms in summer and fall were of this magnitude. Many storms in summer and fall had low mean rainfall values, but some of them produced moderately large amounts at a few raingages within the network.

In each season the average number of storms which produced mean network values of 0.5 inch or more was about 50 percent of the number of 0.25-inch or greater storms. Thus, the 0.5-inch or greater storms represented about 25 percent of the total

winter and spring storms, but only 15 percent of the total number of summer and fall storms. Interestingly, there was very little seasonal difference in the average number of storms which produced 1.0-inch or greater network mean values.

Nearly 50 percent of the average annual number of storms in the Little Egypt Network were associated with thunderstorms. Thunderstorms occurred with 70 percent of all summer storms and with 12 percent of the winter storms. On the average, nine storms per year produced hail within the network and most of these occurred in the spring. Almost 16 percent of all spring storms were associated with hail.



a. FLAT GRADIENT WITH MODERATE TO HEAVY PRECIPITATION (WINTER)

b. FLAT GRADIENT PATTERN WITH LIGHT PRECIPITATION (WINTER)

c. SWATH PATTERN WITH HEAVY SNOW (WINTER-SPRING)

d. IRREGULAR GRADIENT PATTERN WITH LIGHT PRECIPITATION (SPRING)

e. MULTI-CELLULAR WITH MODERATE PRECIPITATION BETWEEN HEAVY PRECIPITATION (SPRING)

f. SINGLE OR MULTI-CELLS OF HEAVY RAIN WITH LITTLE OR NO SURROUNDING RAIN (SUMMER)

g. SINGLE SWATH BY A CELL FROM SOUTHWEST WITH LIGHT TO MODERATE RAIN (SUMMER)

h. SMALL ISOLATED CELLS WITH LIGHT RAIN (SUMMER)

i. NARROW SWATHS OF HEAVY RAIN WITH MODERATE TO HEAVY INTERVENING RAIN (FALL)

FIGURE 4.—Typical patterns of storm preciptation (in inches) found for each season from network data.

Meteorological Findings

Some findings derived from the data collected in the Little Egypt Raingage Network were more directly related to meteorology than to climatology or hydrometeorology. These findings concerned characteristics of the storm periods and the time and space variations in the incidence of precipitation.

Storm Patterns. Certain types of network isohyetal patterns, in regard to shape, configuration, and quantity of precipitation, were found to be prevalent in certain seasons and to occur repeatedly. Each season had one or more typical patterns of precipitation, which are illustrated in Figure 4. As expected, the most prevalent winter storm patterns (Fig. 4a and 4b) had flat gradients with no great variations in amounts with distance. Usually these patterns were oriented so that the heavier storm precipitation occurred in the southern parts of the network. Heavy snow storms frequently produced a swath-like pattern illustrated by the storm map for February 7-8, 1961 (Fig. 4c),

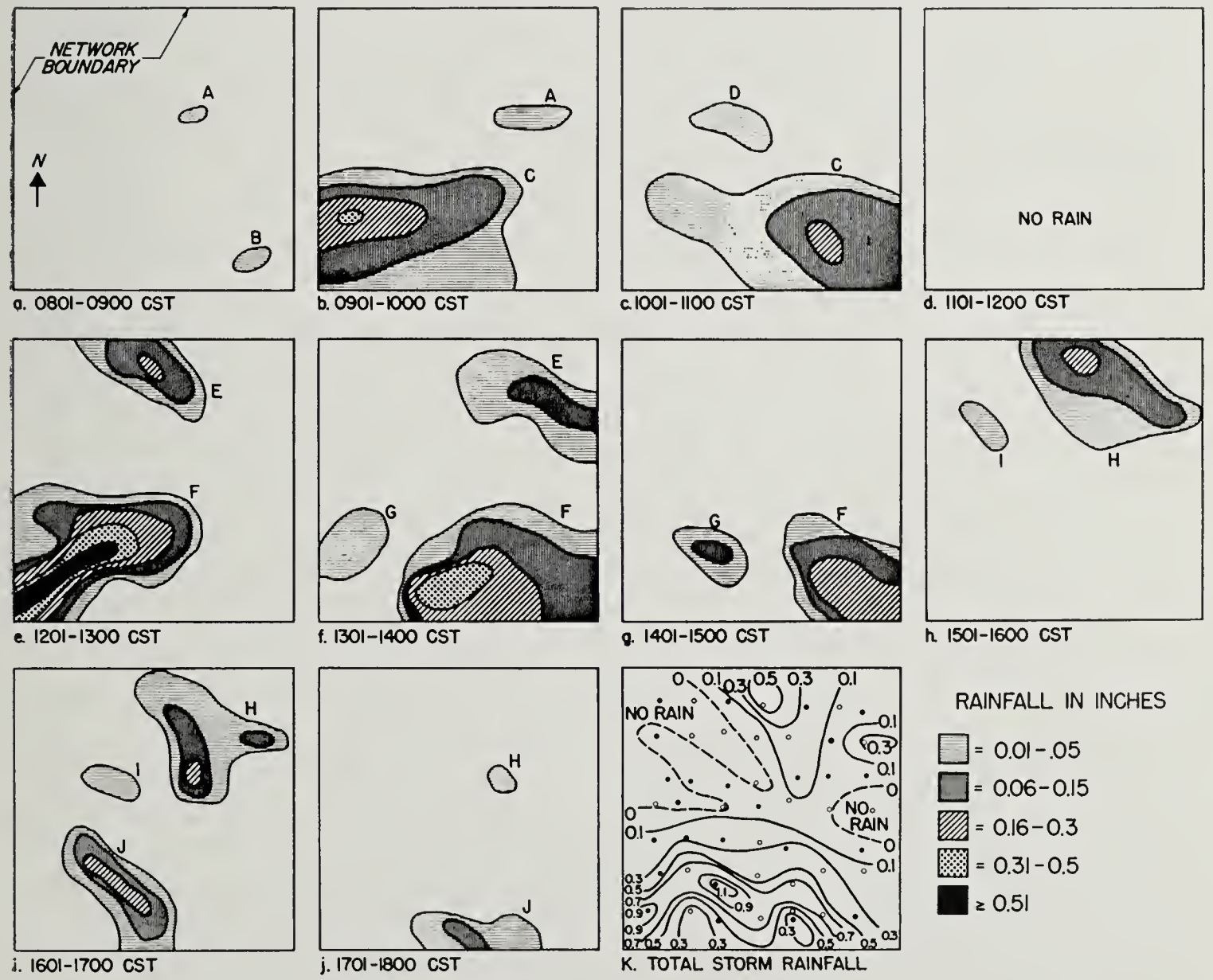


Figure 5.—Maps of the hourly rainfall sequence and total rainfall for the storm of August 21, 1958, illustrating several characteristics of a typical summer storm in the network area.

which produced snow varying from 2 inches in the northern parts to more than 7 inches in the center of the swath.

A typical spring storm pattern associated with light precipitation is shown in Figure 4d. Figure 4e portrays another typical spring storm isohyetal pattern which is characterized by broad swaths of moderate to heavy precipitation which are enveloped by light to moderately heavy precipitation.

Figure 4f shows one of three frequent summer storm patterns. This pattern is often multi-cellular, but the surrounding or intervening areas have little or no measurable rain. Another typical summer storm pattern is caused by a single rain cell which moves across the network from the southwest leaving a narrow swath of light to moderate rainfall (Fig. 4g), and a third (Fig. 4h) is characterized by one or more isolated small cells of light rainfall.

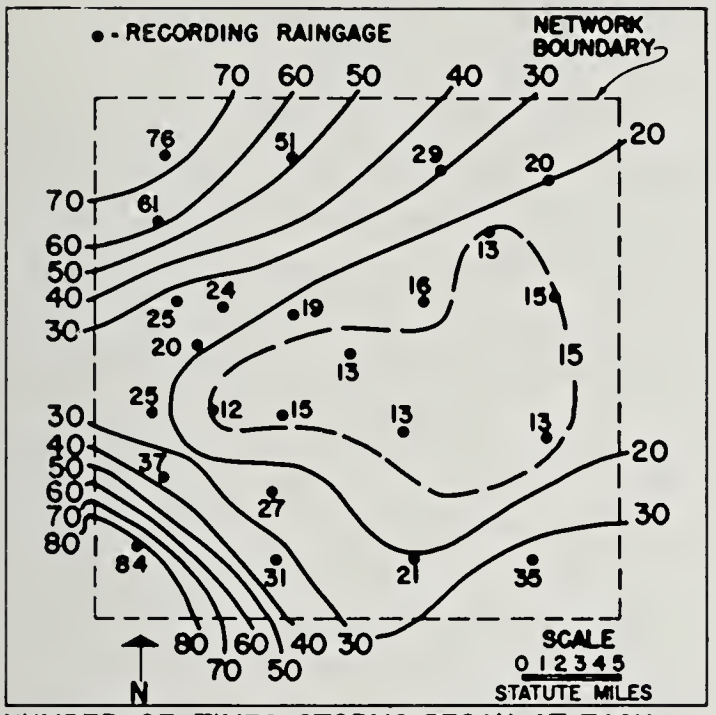
A pattern frequently found in fall season storms of heavy precipitation is shown in Figure 4i. This particular pattern is somewhat similar to the multi-cellular spring storm pattern (Fig. 4e), except that it has narrower swaths of heavy precipitation suggesting the passage of small rainshowers through an area of continuous rain.

Sequence maps in Figure 5 show the rainfall patterns for each hour during the storm of August 21, 1958. The total storm rainfall map (Fig. 5k) has an isohyetal pattern which is representative of one of the typical summer storm patterns (Fig. 4f). An hourly rainfall analysis revealed that this storm was composed of a series of 10 separate cells which either developed in the network or moved across the network.

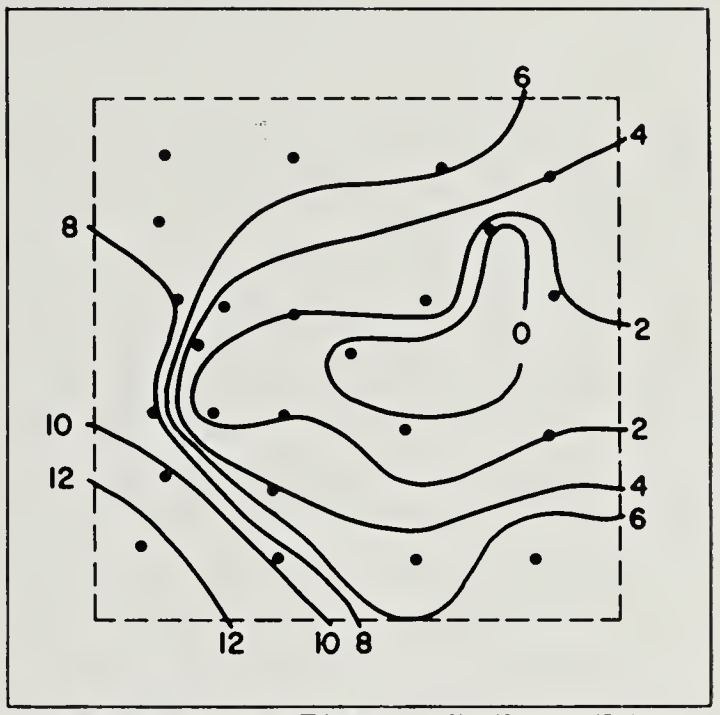
The sequence of hourly maps for Figure 5 is a good illustration of the characteristics of summer rainshowers and thundershowers that constitute a typical summer storm in the network area. The cells which occurred before 12 PM were air mass showers, whereas those in the afternoon were associated with a cold front passage. Cursory examination reveals that some large cells (C, F, H, and J) produced rain over areas ranging from 150 to 300 square miles. However, many of the smaller cells (A, B, D, and I) produced rain over areas of only 5 to 25 square miles. During the ten-hour period of this storm the 10 rain cells assumed a wide variety of sizes, shapes, speeds and directions of movement, and rainfall intensities. This type of storm analysis was made for other summer storms, and results showed that many such summer storms were a composite of four or more rain cells.

Network Initiation of Storms. Two analyses of the initiation of storms in the network were made utilizing the 1958-62 data from the 24 recording raingages. One dealt with the areal variations in the initiations, and the other concerned temporal variations.

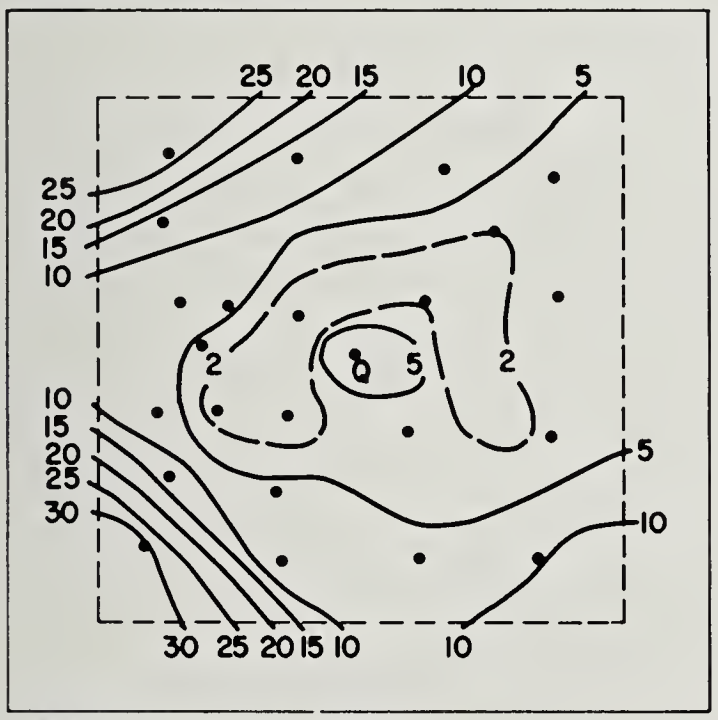
Data for storms starting in the central part of the network, obtained from the 10 interior gages, were compared with records of storm-starts at the 14 gages on the network perimeter. By such a separation, initiation data for developed precipitation systems which moved into the net-



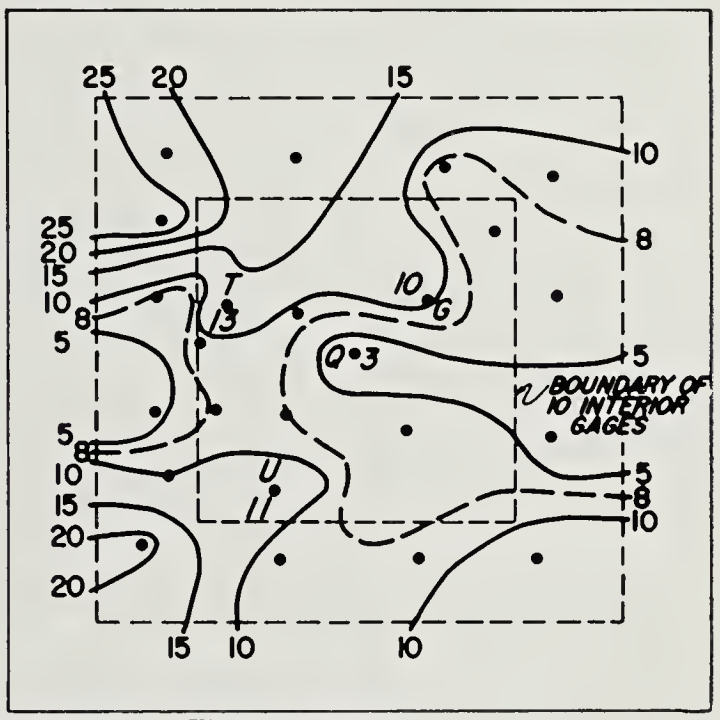
a. NUMBER OF TIMES STORMS BEGAN AT EACH RAINGAGE, 1958-1962



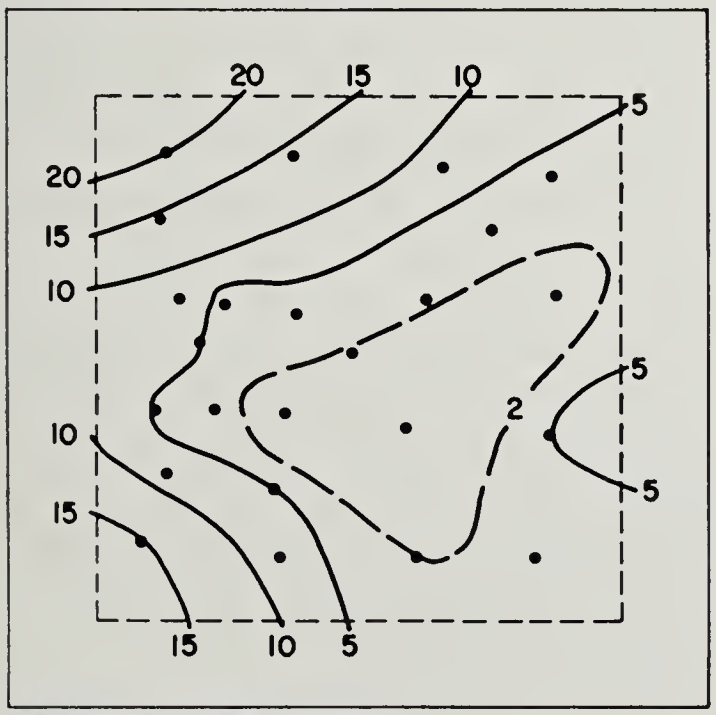
b. NUMBER OF TIMES STORMS INITIATED DURING WINTER



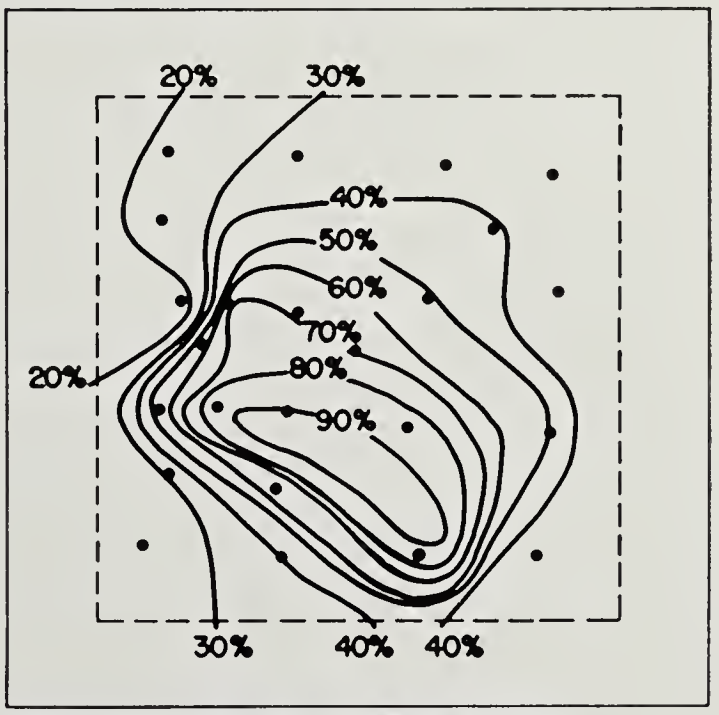
c. NUMBER OF TIMES STORMS INITIATED DURING SPRING



d. NUMBER OF TIMES STORMS INITIATED DURING SUMMER



e. NUMBER OF TIMES STORMS INITIATED DURING FALL



f. PERCENT OF SUMMER STORMS WHICH INITIATED BETWEEN 0900 AND 1500 CST

FIGURE 6.—Maps showing the annual and seasonal distributions of storm initiations in network. Note the high percentage of storms moving into the area from westerly directions.

work could be compared with data for precipitation developing within the confines of the network.

Annual and seasonal areal variations in the initiation of storms are displayed in Figure 6. Most major precipitation systems in Illinois have been shown to move from westerly directions, and a preponderance of movements are from either the southwest or northwest (Changnon and Huff, 1961). The areal distribution shown for all storms in the 1958-62 period (Fig. 6a) reveals the great frequency of storm initiations recorded at the three northwesternmost and three southwesternmost raingages. The number of initiations at these six gages accounted for 50 percent of the total storms in the network. Initiations were least frequent in the 225-square-mile central area (see boundary indicated on Fig. 6d), where the initiations totaled 172 or 24 percent of the total storms. This total represents an annual average of 34 localized developments in the central area.

Seasonal variations in the areal distribution of initiations are shown in Figure 6b-e. The patterns for winter and spring indicate a principal maxima of initiations in the southern and southwestern parts of the network. Apparently rain-producing systems in these two seasons in southern Illinois moved most frequently from the south-southwest. The number of storm initiations in the interior of the network was very small in both of these seasons.

In the summer season also (Fig. 6d), most of the initiations were in the northwest and southwest corners of the network. Considerable variation exists in summer between the number of initiations at nearby raingages as revealed by the pattern along the western network boundary. One-third of the 249 summer storms initiated at the 10 interior gages (Fig. 6d), but less than 20 percent of the total storms in the other three seasons started there. Frequency pattern within this interior reveals a marked tendency for occurrences in the northern, western, and southwestern parts (gages T, G, and U). In the five-year period analyzed, a total of 85 summer storms, an annual average of 17, developed within the 225-square-mile area.

Figure 6e shows the pattern of initiations for the fall season with a principal maximum in the northwestern corner of the network and a secondary maximum in the southwest corner. In the fall and summer precipitation-producing systems in southern Illinois apparently moved from the northwest more frequently than from the southwest which reverses the tendency for the winter and spring seasons.

The diurnal variations in the number of initiations by season and for all 702 storms are shown in Figure 7. Winter storm initiations in the network were most frequent between 3 and 4 AM with a secondary maximum from 5 to 6 PM. The spring season diurnal distribution has four peaks in the frequencies with little agreement with the winter distribution.

The summer season diurnal distribution of initiations has a pronounced maximum occurring between 12 and 3 PM. As indicated previously, many of the 172 storms which initiated within the network interior area occurred in the sum-

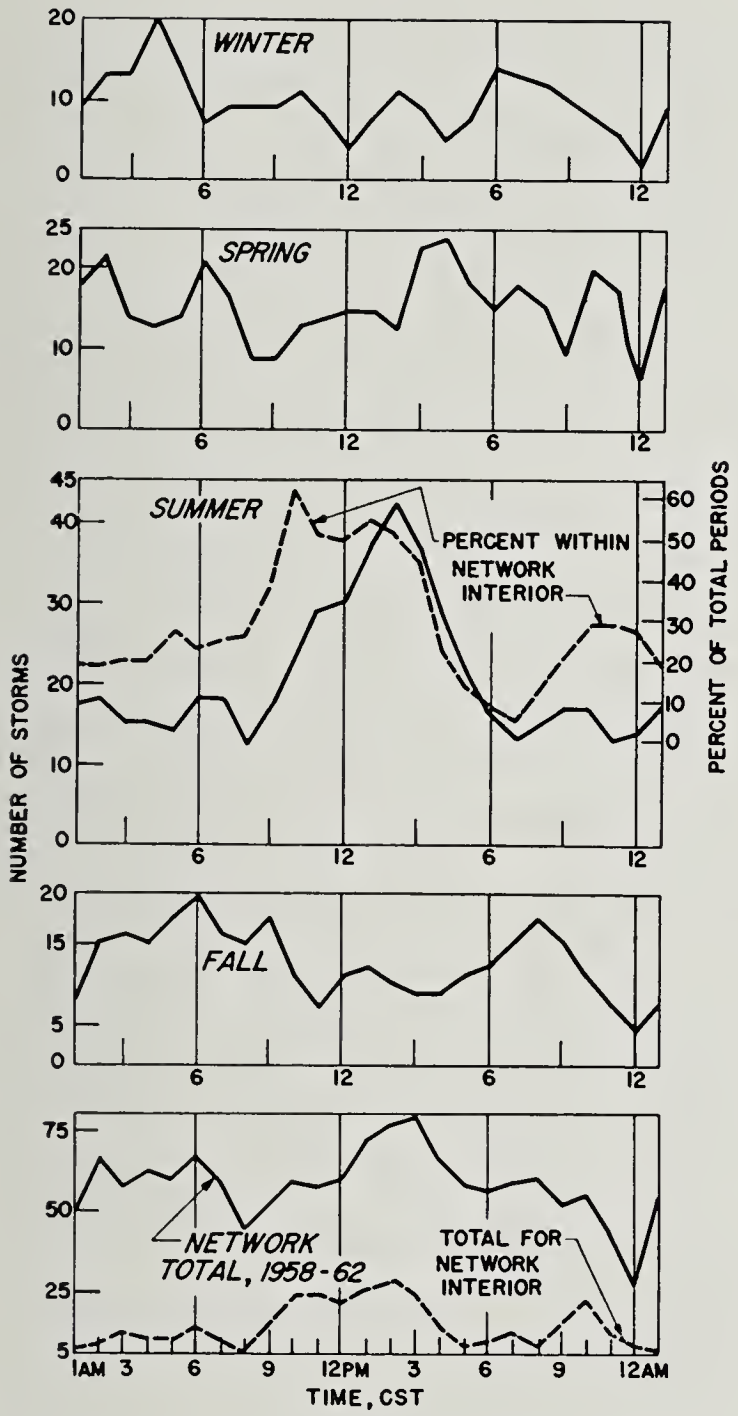


FIGURE 7.—Diurnal graphs showing the total hourly number of storm initiations in each season and for the five-year period. The values shown for each hour are two-hour moving totals. Network storms started most frequently in early afternoon, least frequently near midnight.

mer. From 9 AM to 2 PM the formations of storms in this interior accounted for more than 50 percent of all the network storm initiations for the summer, and therefore largely account for the mid-day peak found in the summer hourly frequencies (Fig. 7). Formations in these hours suggest that most of these storms were localized air mass showers that often depend on mid-day heating for their development. Chiang (1962) has shown that in summer months warm, moist tropical air masses are present more than 50 percent of the time in southern Illinois. The areal significance of storm developments in the mid-day hours is further revealed by the iso-percentile pattern on Figure 6f which is based on the number of storm initiations in the six-hour period ending at 3 PM. The fall diurnal distribution (Fig. 7) is somewhat similar to the winter distribution with maxima occurring in the early morning and early evening.

The diurnal distribution of initiations for all 702 storms in the five-year period of record, also in Figure 7, shows the maximum number between 2 and 3 PM and the minimum between 11 PM and 12 AM. Also shown in this figure is the diurnal distribution of initiations for all storms within the network interior, which again reveals the strong preference for development of these storms in the hours between 9 AM and 3 PM.

Duration of Storms. For each of the 702 storms that occurred in the network during 1958-62, an average duration of precipitation at any location within the network was obtained by averaging the precipitation duration values for all the recording raingages which had measurable precipitation. The average point duration values calculated from all the storms in each season and year are listed in Table 2. The mean duration of storms in the winter was more than four times as great as the mean duration of storms in summer.

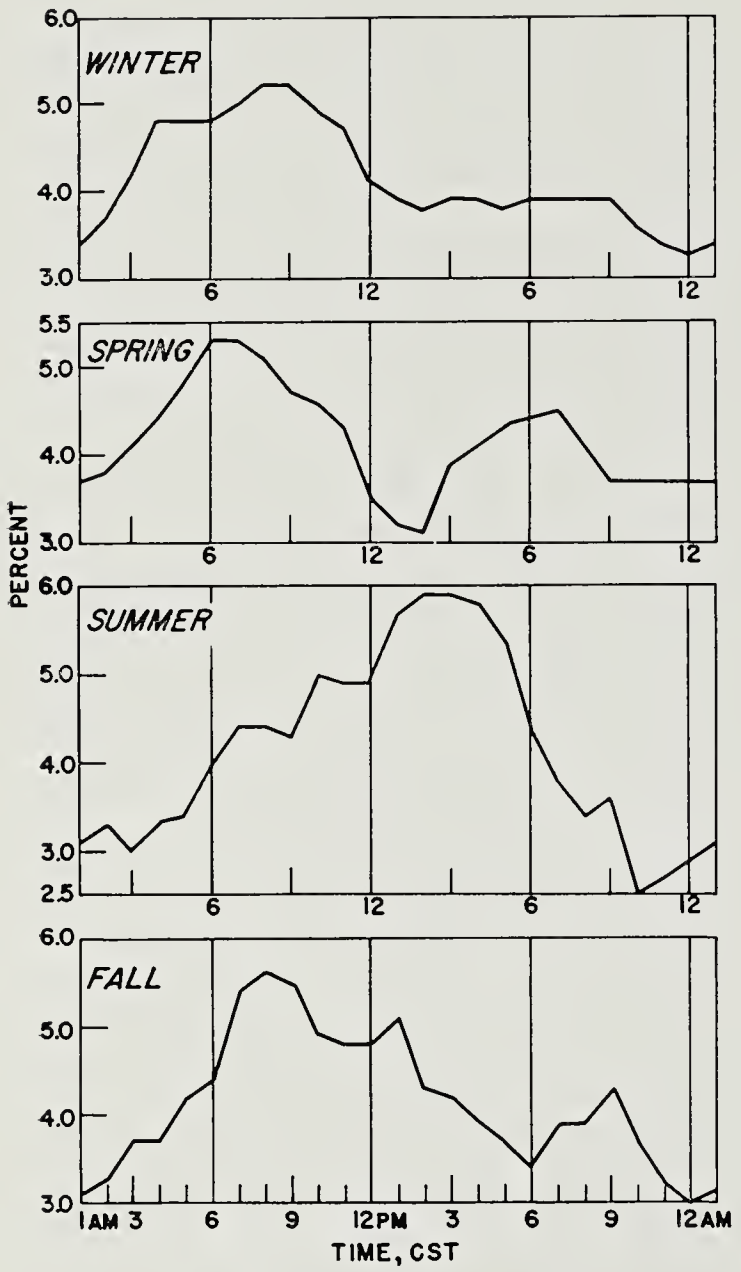


FIGURE 8.—Diurnal graphs showing the hourly frequencies of precipitation occurrence in the network in each season. The number of instances of precipitation per hour are expressed as a percent of the total hours of precipitation in each season. Precipitation was most frequent between 12 and 5 P.M. in summer, but between 4 and 10 A.M. in other seasons.

The average number of calendar days with measurable precipitation in the network is 150 per year (Table 2), or 40 percent of the total days, and long-term records reveal that at a point in the network area the average number of days with measurable rain is 115 (Anon., 1947), which is 32 percent of the total days in a year. However, the average annual number of hours with measurable precipitation at any point within the network is 769 hours which is about 9 percent of the total hours in a year.

Diurnal variations in the frequency of hours with precipitation are shown in Figure 8. In the winter, spring, and fall precipitation was most frequent between 4 and 10 AM; in summer it was most frequent from 12 to 5 PM. In winter, summer, and fall the hours when precipitation was least frequent were between 10 PM and 12 AM, whereas in spring precipitation was least frequent between 12 and 2 PM.

Hydrometeorological Findings

Of primary hydrometeorological interest in the the data from the Little Egypt Raingage Network were storms which produced heavy precipitation throughout or on small parts of the network. Storms which met one of two requirements pertaining to rainfall intensity were selected for analysis. The storms selected were (1) those with a network mean precipitation of 0.5 inch or more, or (2) those which produced rainfall amounts equal to or in excess of the amounts expected to occur at a point once every two years. Characteristics of storms with network mean precipitation values of 0.5 inch or greater were selected for one analysis because these storms produced nearly 70 percent of the total precipitation for the network. Information about storms producing excessive rainfall values is used in the design of hydrologic structures.

Storms with Network Means of 0.5-Inch or More. In the 1958-62 period, 136 of the 702 storms had a network mean precipitation value of 0.5 inch or greater. The average annual number of such moderately heavy storms was 27; highest number in one year was 33 in 1958 and lowest number was 21 in 1959. These moderately heavy storms represent only 19 percent of the total storms in the period; however, they were responsible for 68 percent of the network's total precipitation, and thus were selected for detailed study.

In Table 2, certain seasonal and annual statistics of these heavier precipitation periods are presented. The greatest number of these storms occurred in the spring which has an average of nearly 10 such storms per year; the fewest storms occurred in fall which has an average of five per year. Averaging the network mean precipitation values for these storms for each season showed the highest values (1.29 inches) in summer and the lowest (0.91 inch) in spring.

In all seasons except winter most of these heavier rainstorms were associated with thundershowers which occasionally were mixed with rainshowers. In the winter season more of these storms were with rain-rainshowers, or with rain mixed with snow, than with thundershowers. Only one of the winter storm periods was a snow storm, but three of the 48 spring storms were solely snow storms.

The number of bursts of precipitation, or sudden changes in precipitation rate, during the 136 heavier storms was determined on a seasonal and annual basis. For all 136 storms, a total of two bursts per storm was most frequent. On a seasonal basis, two bursts per storm were most frequent in summer and fall, whereas one burst was most common in spring and three bursts were characteristic of the winter storms.

Initiation data for these storms of 0.5 inch or greater were compared with those for the total 702 storms. The mapped frequency of initiations of the heavier rain periods had a pattern generally similar to that for all storms (Fig. 6a). These heavier network storms frequently were precipitation systems that moved into the network rather than systems that developed within the network area. However, one-third of all the heavier rainstorms in summer formed within the network, which is the same ratio obtained for all network summer storms.

The time of initiation of the heavier storms was also investigated and compared with the data for all network storms (Fig. 7). The 0.5-inch and greater storms initiated most frequently between 2 and 4 AM and between 6 and 8 PM, whereas the major initiation peak for all 702 storms was between 1 and 3 PM. The diurnal distributions of initiations of the heavier storms in the winter and spring seasons were similar to those obtained for all the storms (Fig. 7). In the fall the heavier storms initiated most frequently between 8 and 9 PM in contrast to the peak on initiations for all storms between 5 and 6 AM. In summer most of these heavy storms initiated between 7 and 9 PM.

TABLE 3.—Two-Year Frequency Amounts for Southern Illinois and Number of Network Storms which Produced Two-Year or Greater Frequency Amounts for Varying Durations.

Duration	Amounts to be equalled or exceeded at least once every two years, inches	Number of storms with at least one raingage amount equal to or greater than two-year value				
		Winter	Spring	Summer	Fall	Annual Average
30 min	1.1	1	16	31	9	11
1 hr	1.4	1	10	27	6	9
2 hrs	1.7	0	6	17	5	6–
3 hrs	1.9	0	6	16	4	5
6 hrs	2.2	1	6	15	5	5
12 hrs	2.8	0	3	11	4	4–
24 hrs	3.2	0	3	9	3	3
Average	–	1–	4–	8–	2	–

The average point duration of the 0.5-inch or greater storms was 12.3 hours, compared with 5.6 hours for all storms (Table 2). This tendency to have durations in excess of the average duration for all storms also prevailed in each of the four seasons.

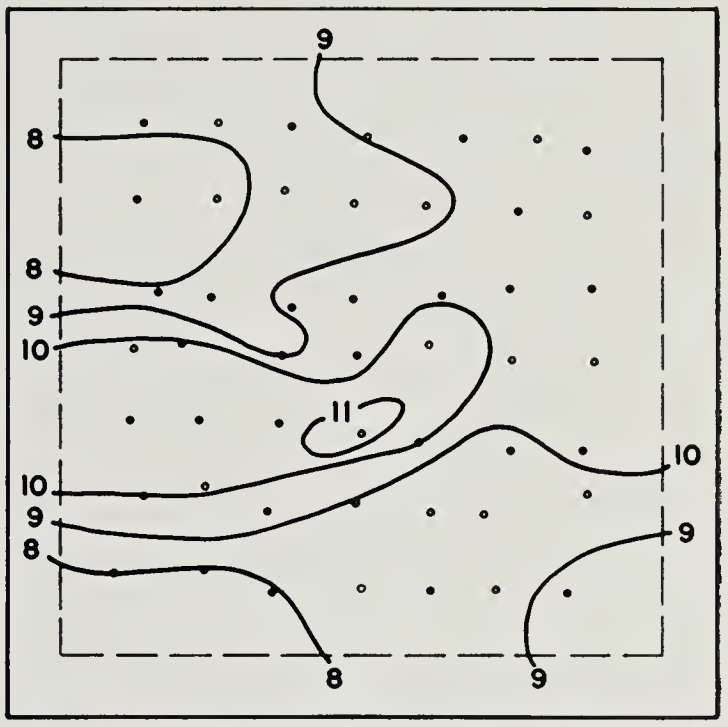
Storms with 2-year Frequency Amounts. All storms with one or more gaged amounts equal to or in excess of the amounts expected to occur at a point in Southern Illinois at least once in a two-year period for any one of seven durations between 30 minutes and 24 hours were selected for analysis. During the 1958-62 period, 70 storms, or almost 10 percent of the total number, produced a two-year frequency amount for one or more of the seven possible durations. Table 2 shows the seasonal and annual average number of storms with two-year excessive rainfall values.

Huff and Neill (1959) have identified the two-year frequency amounts expected in Southern Illinois for each of the seven durations, and these are listed in Table 3. The number of network storms which produced two-year frequency amounts is also listed. Only 15 of the 70 storms had 24-hour amounts equalling or exceeding the two-year value of 3.2 inches for this duration. However, 57 of the 70 storms had 30-minute amounts of 1.1 inches or more. As shown in Table 3, the network annual averages diminish with increasing duration.

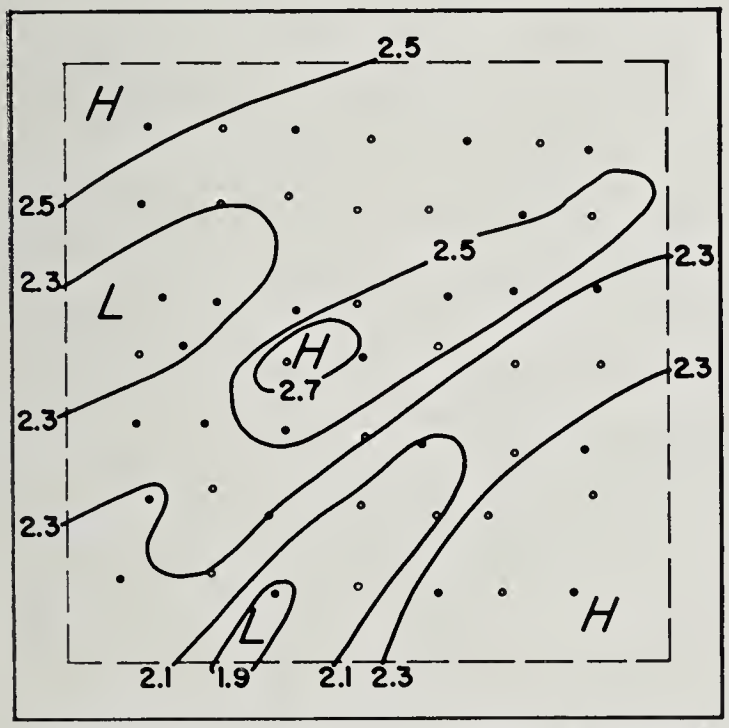
Data in Table 3 indicate that more than 50 percent of the storms with excessive rainfall amounts occurred in summer which has an average of eight such storms per year. Only two storms with two-year frequency amounts occurred in winter.

Examples of four storms which produced excessive rainfall amounts are shown in Figure 9. The most severe short-duration rainstorm in the network during the 1958-62 period occurred during the night of August 16-17, 1959 (Huff and Changnon, 1961). Each network raingage (Fig. 9a) had amounts in excess of the two-year recurrence interval value for all durations from 30 min-

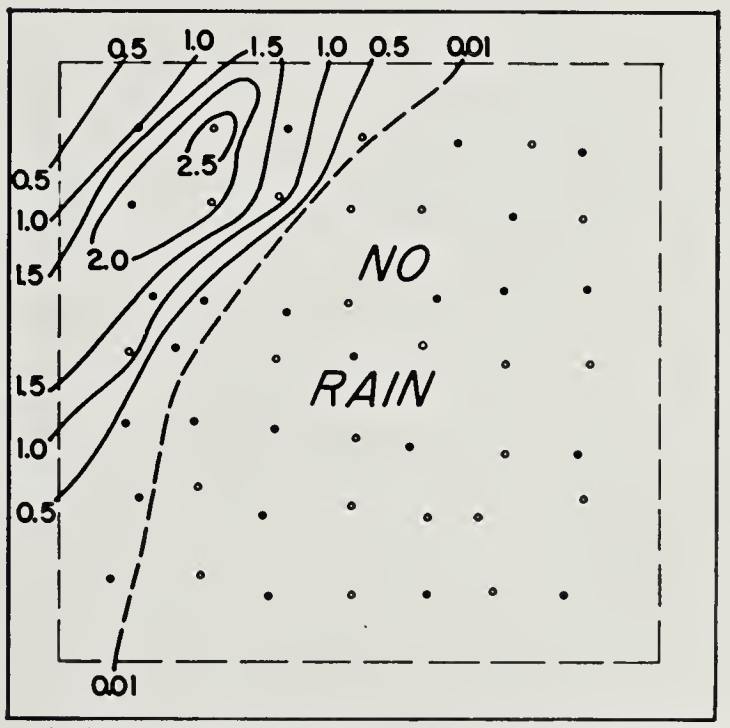
a. TOTAL STORM RAINFALL, AUGUST 16-17, 1959 (16 HOURS)



b. TOTAL RAINFALL FOR 4 STORMS IN MAY 5-8, 1961 (96 HOURS)



c. TOTAL STORM RAINFALL, JANUARY 21-22, 1962 (22 HOURS)

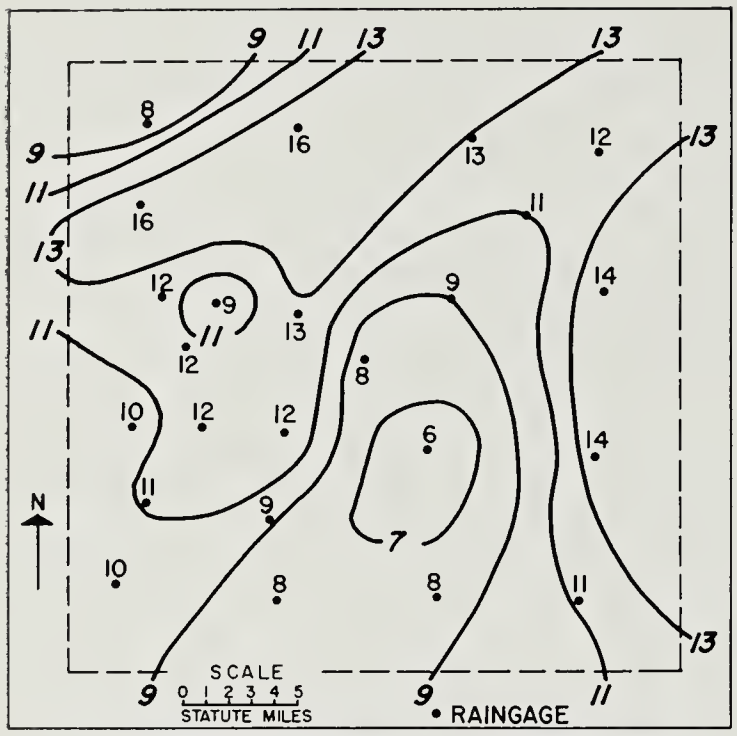


d. TOTAL STORM RAINFALL, JULY 11, 1961 (2.4 HOURS)

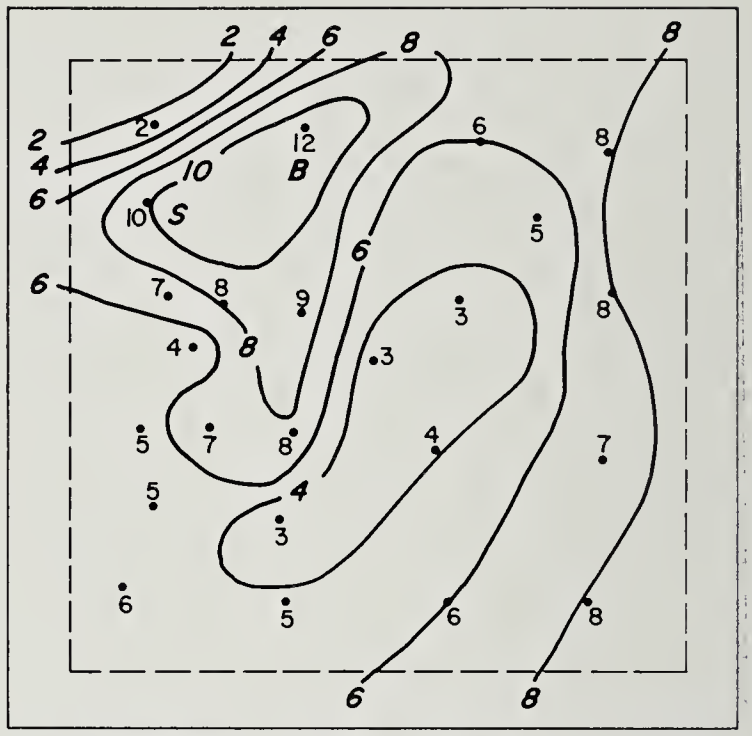
FIGURE 9.—Isohyetal patterns of selected storms which produced excessive point rainfall amounts in the network during the 1958-1962 period. Total rainfall throughout the network in the August 16-17, 1959 storm exceeded the once in 100-year recurrence interval for a 16-hour period.

utes to 24 hours. Four intense rainstorms occurred in a four-day period during May 1961, and the resulting four-day total precipitation pattern is presented in Figure 9b. Each of the four storms comprising this period had values in excess of certain two-year frequencies. Figure 9c depicts the isohyetal pattern for a winter storm which produced six-hour amounts in excess of the two-year frequency values for this duration.

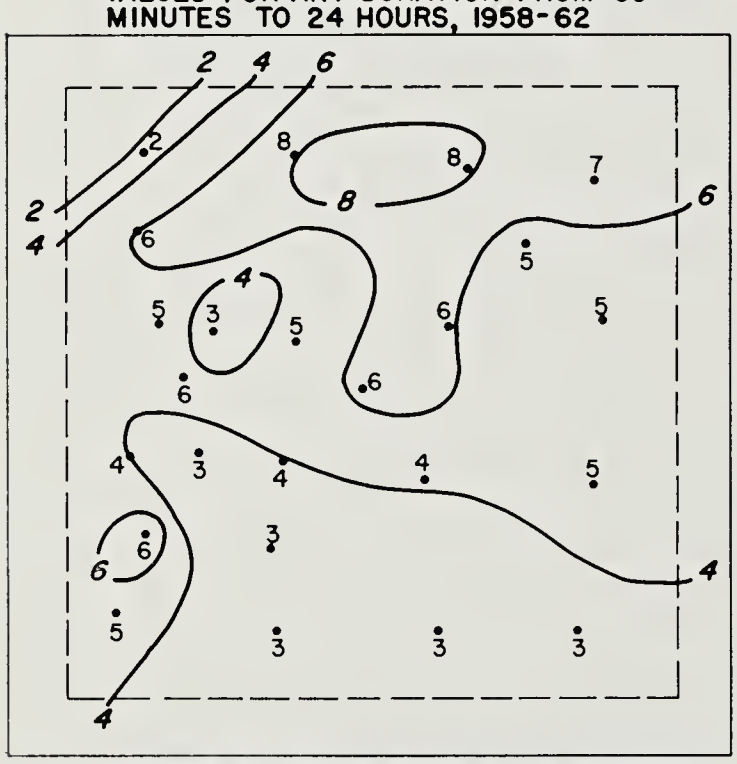
Using the network mean precipitation values for these 70 storms, an average value of 1.02 inches was



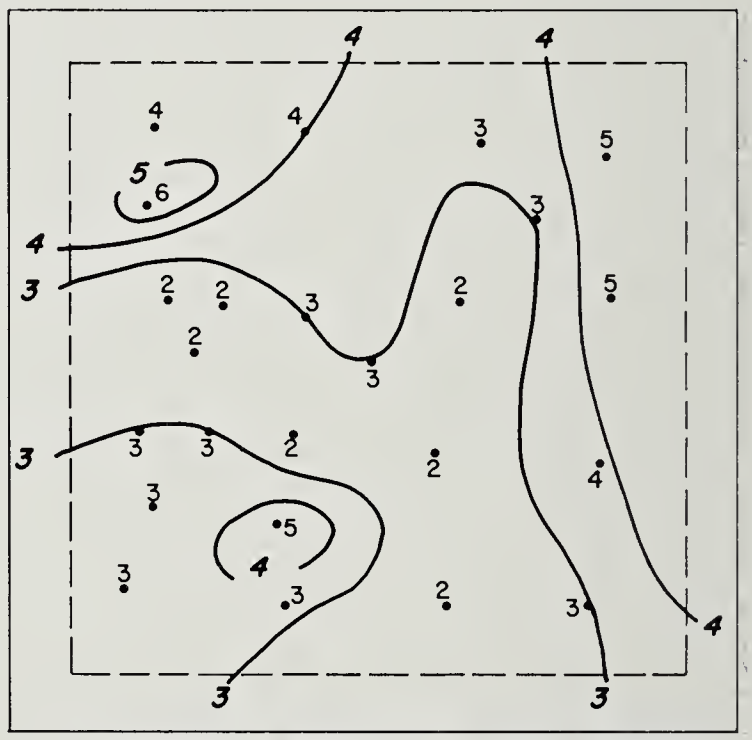
a. NUMBER OF STORMS THAT PRODUCED 2-YEAR OR GREATER RECURRENCE INTERVAL VALUES FOR ANY DURATION FROM 30-MINUTES TO 24 HOURS, 1958-62



b. NUMBER OF TIMES EACH GAGE RECORDED A 30-MINUTE AMOUNT ≥ 2-YEAR RECURRENCE INTERVAL VALUE (1.1 in.)



c. NUMBER OF TIMES EACH GAGE RECORDED A 6-HOUR AMOUNT ≥ 2-YEAR RECURRENCE INTERVAL VALUE (2.2 In.)



d. NUMBER OF TIMES EACH GAGE RECORDED A 24-HOUR AMOUNT ≥ 2-YEAR RECURRENCE INTERVAL VALUE (3.2 In.)

FIGURE 10.—Number of times that two-year or greater recurrence interval rainfall values occurred at each recording raingage in the network during the study period are shown for selected durations.

computed. However, many of the 70 storms produced little or no precipitation in large parts of the network area. Consequently, 26 of the 70 severe storms had network mean values lower than 0.5 inch, and 15 of these had network mean values lower than 0.3 inch. As an example, the storm on July 11, 1961 (Fig. 9d), had excessive values for the durations from 30 minutes through three hours, but the network mean rainfall was only 0.25 inch.

Three analyses of the areal dis-

tribution of two-year frequency amounts within the network were performed. For each duration the point frequencies of two-year amounts were computed and areal variations of the point frequencies within the network were compared. Next, the point and network (area) frequencies of excessive amounts for each duration were compared to measure the point-areal relationship of excessive rainfall occurrences. Last, the relationship between the occurrence of frequency values at different numbers of network gages during a storm was ascertained.

The number of storms that produced two-year or greater frequency amounts for any duration from 30 minutes to 24 hours at each raingage is portrayed in Figure 10a. Considerable areal variation is apparent with the highest numbers of excessive storms recorded at the raingages in the northwestern and eastern areas where the average annual precipitation was found to be greatest (Fig. 2). Excessive storms were least frequent at raingages in the southern parts where the average annual precipitation was least.

In Figure 10b the number of two-year or greater frequency amounts for 30-minute periods recorded at each of the 24 recording raingages is depicted. If a normal number had occurred at a point, two or three such events would be expected during a five-year period. However, many raingages had more than twice the expected number, and some gages (B and S) had four to five times as many as could be expected. The two-year or greater frequency amounts recorded at each raingage for six-hour periods (Fig. 10c) and for 24-hour periods (Fig. 10d) show less areal variation than occurred with the 30-minute amounts, and most raingages recorded the statistically expected number of excessive 24-hour amounts.

To obtain a measure of the relationship between frequencies of excessive amounts at a point and the network or areal frequencies of excessive amounts, an areal-point comparison was made for each duration

TABLE 4.—Areal and Point Rainfall Frequency Values Equal to or Greater Than Two-Year Recurrence Values, 1958-62.

	Number of cases for given period						
	30 min	1 hr	2 hrs	3 hrs	6 hrs	12 hrs	24 hrs
Median number per gage.....	6	5	5	4	5	3	3
Maximum number at any gage....	12	10	9	8	8	6	6
Minimum number at any gage....	2	3	2	2	2	1	2
Network total....	57	44	28	26	27	18	15
Average ratio, network single (point) gage....	9.5	8.9	5.6	6.5	5.4	6.0	5.0

TABLE 5.—Percent of Time that Excessive Amounts Occurred at Different Numbers of Gages During Storms.

Duration of excessive amounts	Average percent of the time that specified numbers of gages experienced two-year or greater amounts			
	2 or more gages	3 or more gages	4 or more gages	12 or more gages
30 min	86	63	50	5
1 hr	83	61	55	17
2 hrs	80	77	69	26
3 hrs	85	76	75	25
6 hrs	92	78	72	31
12 hrs	95	68	65	30
24 hrs	95	55	50	30

for the two-year frequencies (Table 4). A mean ratio for all durations of 6.7 was obtained for the frequency of areal to point occurrences. This indicates that, on the average, there were nearly seven times as many excessive rainfall amounts observed in the 550-square-mile network area as were observed at any point in that area. The average ratios for the seven durations differed, and the ratios decreased with increasing duration. Excessive rainfall amounts for 30-minute and one-hour periods occurred nine times more frequently in the 550-square-mile area than at a point within the area.

The areal extent of excessive amounts during storms with two-year or greater frequency amounts was also investigated. Using the 12 raingages lettered A through P (Fig. 1), which are evenly dispersed throughout the network, the relationship between the occurrence of excessive amounts of precipitation at different numbers of raingages was measured for individual storms. The number of raingages recording excessive amounts each time one of these 12 selected raingages had an excessive amount was recorded for each of the seven storm durations.

The long-duration excessive amounts, 12 to 24 hours, (Table 5) frequently were either relatively localized or relatively widespread. This is revealed by the relatively high percentages under two-or-more gages and under twelve-or-more gages, and by the relatively low percentages for three-or-more gages and four-or-more gages. The excessive storms with durations of two to six hours had relatively high percentages for the three-or-more gages and four-or-more gages categories, but the areal extent of excessive amounts was less than that for the storms with longer durations. The low percentages for the 30-minute and one-hour periods for the four-gage and twelve-gage categories reveal that such short duration excessive rainfall periods were considerably more localized

TABLE 6.—Percentage of all Excessive Amounts Occurring in Storms with Varying Durations and Amounts Equal to or Greater than Two-Year Frequency Values.

Duration	Total number of storms in network	Percent of total storms for each duration occurring with excessive amounts for indicated durations				
		30-min	1-hr	3-hr	12-hr	24-hr
30 min	57	–	63	42	23	19
1 hr	44	82	–	57	36	30
2 hrs	28	82	90	90	54	43
3 hrs	26	92	96	–	58	50
6 hrs	27	74	85	81	67	56
12 hrs	18	72	90	83	–	83
24 hrs	15	73	87	87	100	–

than those with longer durations.

Almost 30 percent of the 70 excessive storms first produced rainfall at the ten raingages in the network interior. Initiations at gages A, B, S, and M (Fig. 1) accounted for 46 percent of the 70 initiations. More than 50 percent of all 70 excessive storms initiated between 12 and 9 PM. The three-hour period with the greatest number of excessive rainstorm initiations was 12 to 3 PM in contrast with 12 to 3 AM for the storms producing network means of 0.5 inch or more. The average point duration of rainfall for the 70 storms was 6.3 hours.

The frequency with which excessive amounts for different durations occurred during the same storms was investigated, and the results are shown in Table 6. More than 72 percent of all storms with 12-hour and 24-hour frequency values also had two-year or greater frequency values for all the shorter durations. However, many of the storms with 30-minute frequency values did not produce other longer-duration excessive amounts. For instance, only 19 percent of the storms with 30-minute amounts were associated with 24-hour excessive values. A 30-minute value was associated most frequently with a one-hour excessive value; a three-hour value occurred most frequently with a one-hour value; and a 24-hour value occurred more frequently with a 12-hour value than with an excessive value for any other duration. The percentages in Table 6 for the 30-minute durations are much lower than those obtained for a 10-square-mile raingage network in central Illinois (Huff and Changnon, 1960).

SUMMARY

Five years of data from a network of 49 raingages within a 550-square-mile area of southern Illinois, after careful analysis, have provided highly useful and some new precipitation statistics. The findings have been sorted and studied according to

climatological, meteorological, and hydrometeorological applications.

1. The average annual precipitation pattern for the 1958-62 period revealed considerable areal variation with a maximum difference of six inches between amounts at raingages separated by only a five-mile distance.

2. The distribution of the average annual precipitation during 1958-62 did not associate well with variations in the surface elevation, but the pattern did appear to be somewhat correlated with areal distribution of the number of excessive short duration rainfall amounts.

3. The average seasonal precipitation patterns for all but the winter season had much greater areal variability than did the long-term mean seasonal precipitation patterns for the network areas.

4. The average annual number of storms within the network was 140.

5. The average annual number of hours with precipitation at any point within the network was 770 which is nine percent of the year.

6. Nearly 50 percent of all network storms were associated with thunderstorms.

7. Nine types of precipitation patterns for storms were found to recur frequently, and many summer storms were composed of a series of four or more small rain cells.

8. More than 75 percent of all storms in the network were produced by systems moving into the area from the southwest, west, or northwest.

9. Storms initiated most frequently in the early afternoon and least frequently near midnight.

10. In a 225-square-mile area an average of 17 storms developed locally in summer, principally between 9 AM and 3 PM, and on the average 34 storms developed within this area during an entire year.

11. All network storms had an average point duration of 5.6 hours; the average was 11.6 hours for winter storms and 2.6 hours for summer storms.

12. In all seasons except summer, precipitation occurred most frequently during the hours between 4 and 10 AM; precipitation was most frequent between 12 and 5 PM in summer.

13. Nineteen percent of all storms had network mean values of 0.5 inch or more, and these storms yielded 68 percent of the total network rainfall.

14. Seventy storms produced excessive rainfall amounts for durations of 30 minutes through 24 hours, and most occurred during the summer season.

15. In general, the number of excessive amounts for durations of 6 hours and less was much greater than expected statistically.

16. The network experienced nearly seven times as many storms with excessive rainfalls as did a given point within the network.

17. Excessive rainfall of short duration normally did not extend over a large portion of the network.

18. Most excessive amounts of longer duration (12 and 24 hours) covered large portions of the network and they also were frequently associated with excessive rainfalls for all shorter durations.

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VEGETATION OF THE PINE HILLS FIELD STATION IN SOUTHWESTERN ILLINOIS

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The Pine Hills Field Station of Southern Illinois University is located in the unglaciated Illinois Ozarks of the southwestern part of the state (Fig. 1). The land was recently acquired on long-term lease from the Trojan Powder Company. A topographic map (Fig. 2) shows details of the ridges, slopes, and floodplain. The area of 258 acres includes on-the-floodplain alluvial or outwash fill deposits and pond and swamp habitats in ancient channel depressions of the Mississippi-Big Muddy River at 350 feet elevation. Adjacent to much of the floodplain is a line of fifty foot or higher massive Bailey Limestone cliffs, highly weathered and capped by cherty gravels of the siliceous Grassy Knob Formation. These represent truncated spur ridges from a central north-south ridge system. Ravine systems at both the northwest and southwest corners of the Station extend from the floodplain approximately one-quarter mile into the highlands. The eastern part drains to the south from a central broad ridge which has narrower prolongations to the north and the south. The upland areas are blanketed by loess which remains on ridges and may be found on ravine slopes. The predominant soil is a silty-clay with

FIGURE 1.—An outline map of the central Mississippi Valley showing the location of the Pine Hills Field Station.

rocky or gravelly phases. Litter is essentially continuous for all forest areas and the upper soil is darkened with organic matter.

Climatically the area has been classified Caf, humid subtropical with warm summers (Trewartha, 1954). Average annual temperature approximates 58° F. (January 36° to July 80° F.) with about 200 frost-free days. Precipitation averages approximately 40 inches with May the wettest month and with a rela-

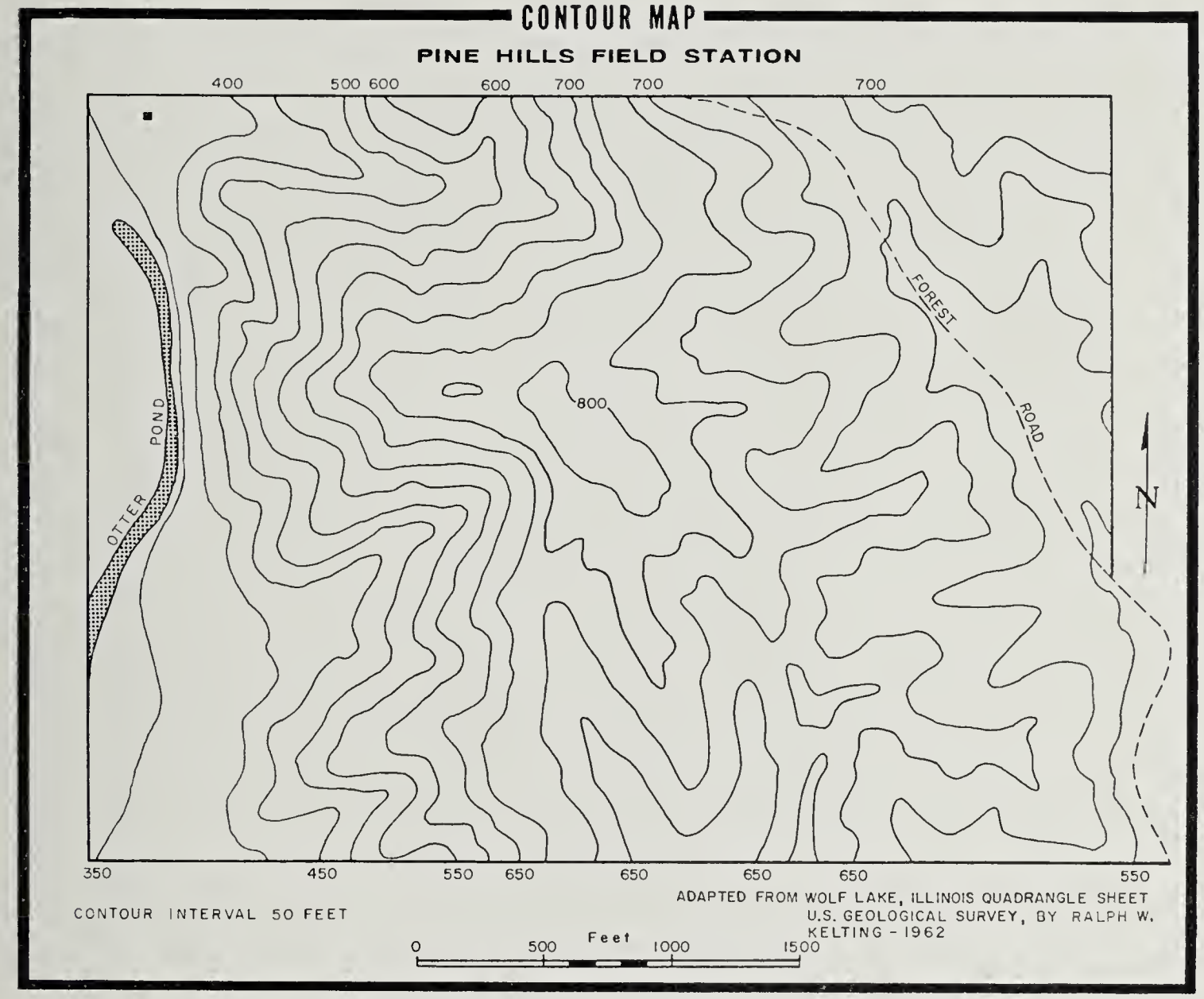

FIGURE 2.—Topographic map of the Pine Hills Field Station.

tively dry summer and early autumn. Snowfall averages 10 to 15 inches annually. Invasions of cold air from the north may bring more typically northern Illinois conditions of severe winter weather, or may ameliorate summer heat. Spring and fall are the seasons of most frequent wild fires in the region. We do not know of fires having occurred on the Station for the past 30 years. This may be related to the general isolation of the area, the swamps on the west, National Forest ownership on the east, north, and west, and protection furnished by the powder manufacturing company on the south. Basal fire scars are present on the uphill side of medium-sized white oak and other trees. Lumbering may have been general over the area at sometime in the past. A widespread distribution of sassafras may be related to this or to fire.

The presence of abundant and diverse animals is shown in numerous studies which have been carried out by workers at Southern Illinois University and other institutions. Direct influences of animal life on plant growth or distribution were not generally evident. Girdling of trees up to 12 inches in diameter by beaver was found in the swamp forests of the floodplain. Wood-

chucks, squirrels, deer, rabbits, foxes, many birds, reptiles, and amphibians were observed. A six-foot chain link fence topped with barbed wire was erected on two sides of the Station in the last two years.

A road cuts across the northeastern corner of the Station and a research building and yard occupy part of the northwestern corner. Except for Otter Pond, the remainder of the area is covered by forest. Comparisons of the United States Department of Agriculture's 1938, 1952, and 1959 aerial photos show increased canopy coverage. Changes in species composition were not detected on these photos.

The Illinois Ozarks are mapped by Shantz and Zon (1924) as Oak-Hickory. Cypress-Tupelo-Red (Sweet) Gum (River Bottom Forest) reaches to the Station area from a more southern occurrence. Braun (1950) maps the Station location at the eastern edge of the Oak-Hickory Forest Region and at the western edge of the Western Mesophytic with the Southeastern Evergreen, Mississippi Alluvial Plain a few miles to the south.

Detailed study in our small area revealed more diverse vegetation than could be shown on the above two maps. Classification and mapping of the plant communities were carried out by the combined use of stereoscopic interpretation of the 1959 U. S. Department of Agriculture aerial photographs at 1:20,000 and by ground surveys. Küchler (1956) presented a full explanation and use of these techniques. In our study, fifty units of visual homogeneity were delineated on the aerial photographs prior to extensive field work. The physical characteristics of tree size, shape, spacing, and reflectance properties of the canopy were those primarily evident under a stereo viewer. After this essentially physiognomic delineation of unit areas, field surveys were carried out. Each unit was walked through one or more times depending on the size of the area. Floristic lists were compiled of the canopy trees, understory trees and shrubs, and herbs. Additional notes were taken on tree sizes, and diameters at breast height (DBH) were recorded for the largest trees. The ecological structure was briefly described. Habitat information included the type of topography, the direction and angle of slope, the extent and thickness of the litter layer, and the surface geology.

After the field data had been obtained, a map for the Station area showing eight plant communities was compiled (Fig. 3). A similar height and density, similarity in the number and kind of strata present, and a similar total species composition and distribution of dominant and indicator species were criteria for grouping certain of the 50 units on the aerial photographs into a given plant community. Greatest importance was placed on the largest trees. Transgressives from one community would frequently be found in others, but often not attaining full growth. The ground surveys resulted in the elimination of some presumed boundaries and in the drawing of a few new ones. The aerial photo outlines were, however, usually found to be the best boundaries for separating two communities on the map and were used in

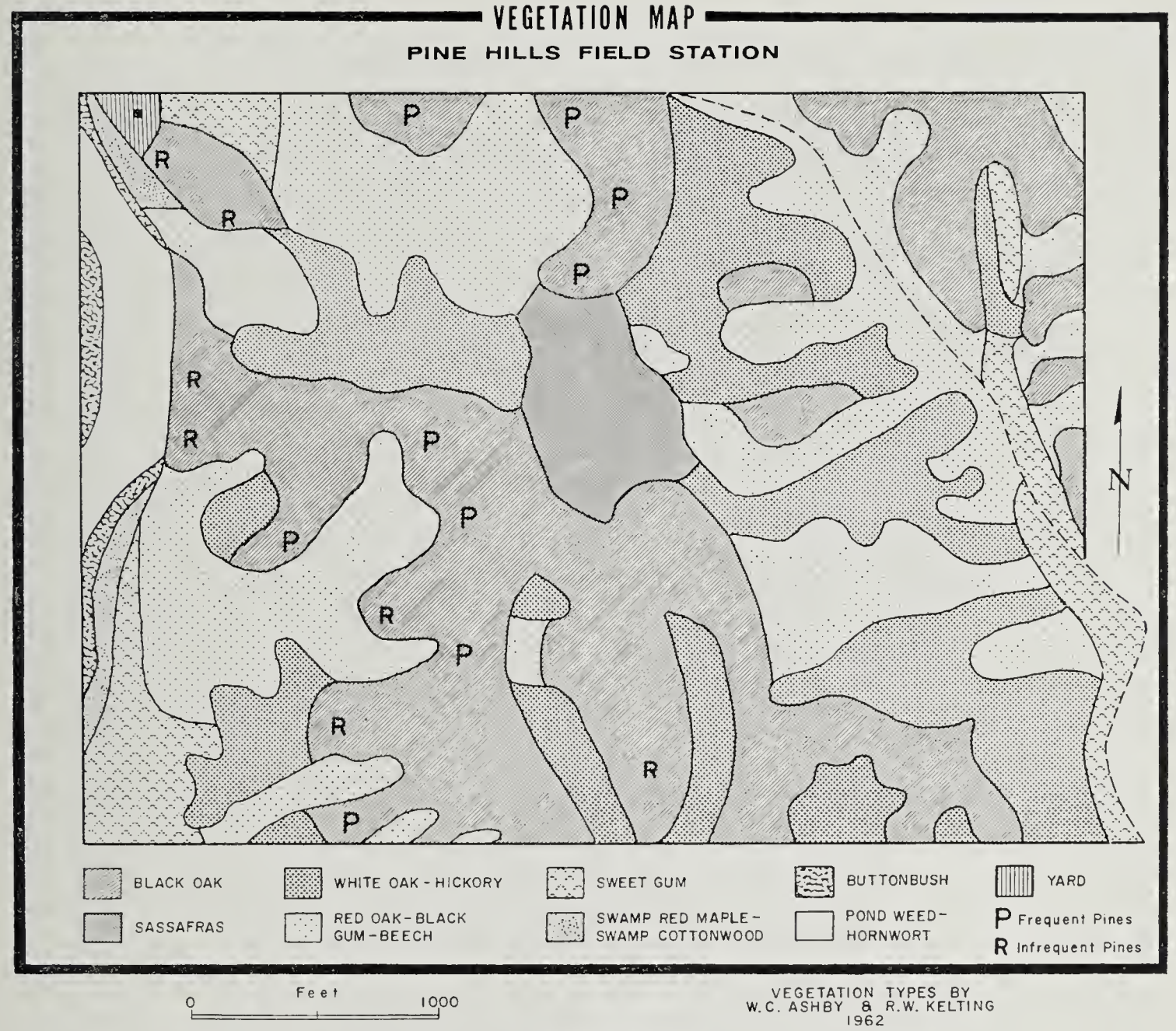

FIGURE 3.—Vegetation map of the Pine Hills Field Station.

the majority of instances. Our emphasis was on functional plant communities, even though a thorough floristic census would very likely be amenable to presentation from the continuum point of view. Further study is continuing in each community described. Permanent plots which would be fully censused for successional studies are planned in conjunction with a survey for a grid system on the Station.

Gray's Manual (Fernald, 1950) was used for names of species. County distribution maps for Illinois (Jones and Fuller, 1955), a manual for southern Illinois (Mohlenbrock and Voigt, 1959), and a checklist for the Pine Hills (Mohlenbrock and Voigt, in press) are available.

Table 1 shows the number of areas for each community, their total percentage area, and their acreage. In field distribution the communities are found in aquatic, bottomland and ravine, or slope and ridge habitats. Aquatic communities can be directly related to the distance from the shore with the Pondweed (*Potamogeton*)-Hornwort (*Ceratophyllum*) furthest out and then the Buttonbush (*Cephalanthus occidentalis*) and, nearest the shore, the Swamp Red Maple (*Acer rubrum* var. *drummondii*)-

TABLE 1.—Areas of the Plant Communities on the Pine Hills Field Station.

Plant community	Number of areas	Percent of total area	Area in acres
A. Yard	1	0.3	0.7
B. Aquatic			
1. Pondweed-Hornwort	1	2.9	7.5
2. Buttonbush	3	1.2	3.1
3. Swamp Red Maple-Swamp Cottonwood	2	1.0	2.6
C. Bottomland and Ravine			
1. Sweet Gum	4	5.0	12.9
2. Red Oak-Black Gum-Beech	15	27.7	71.5
D. Slope and Ridge			
1. White Oak-Hickory	13	25.7	66.3
2. Sassafras	1	3.5	9.0
3. Black Oak	10	32.7	84.4
Total	50	100.0	258.0

Swamp Cottonwood (*Populus heterophylla*) communities. In the bottomland and ravine areas were found the Sweet Gum (*Liquidambar styraciflua*) and the Red Oak (*Quercus rubra*)-Black Gum (*Nyssa sylvatica*) -Beech (*Fagus grandifolia*) communities, each of which embrace an appreciable floristic diversity. On the slope and ridge areas were found the White Oak (*Quercus alba*)-Hickory (*Carya glabra*), the Sassafras (*Sassafras albidum*), and the Black Oak (*Quercus velutina*) communities.

Aquatic Habitats

Pondweed-Hornwort. This community is composed primarily of submerged species. Occasional emergent plants such as yellow water lily (*Nuphar advena*) are found. Duckweeds cover the water where the surface is relatively undisturbed by wind. Sponge plant (*Limnobium spongia*) is common. In summer the plant growth is sufficiently dense to obstruct the movement of a small boat over the entire surface of Otter Pond (Fig. 4).

Buttonbush. Fringing the Pondweed-Hornwort community is a zone of buttonbush which varies from a few to many yards in width. It is relatively pure with some admixture of swamp rose (*Rosa palustris*) and black willow.

Swamp Red Maple-Swamp Cottonwood. Characteristically in shallow standing water adjacent to the shore is a fringing belt up to 75 feet in width with scattered trees of swamp red maple and swamp cottonwood and lesser numbers of pumpkin ash (see Table 2 for tree nomenclature), water locust, and black willow. Pin oak, hackberry, and sugarberry are found on the shore. Scattered shrubs include buttonbush and, along the shore, deciduous holly (*Ilex decidua*), and Virginia willow (*Itea virginica*). The herb layer is locally well-developed, being composed pri-

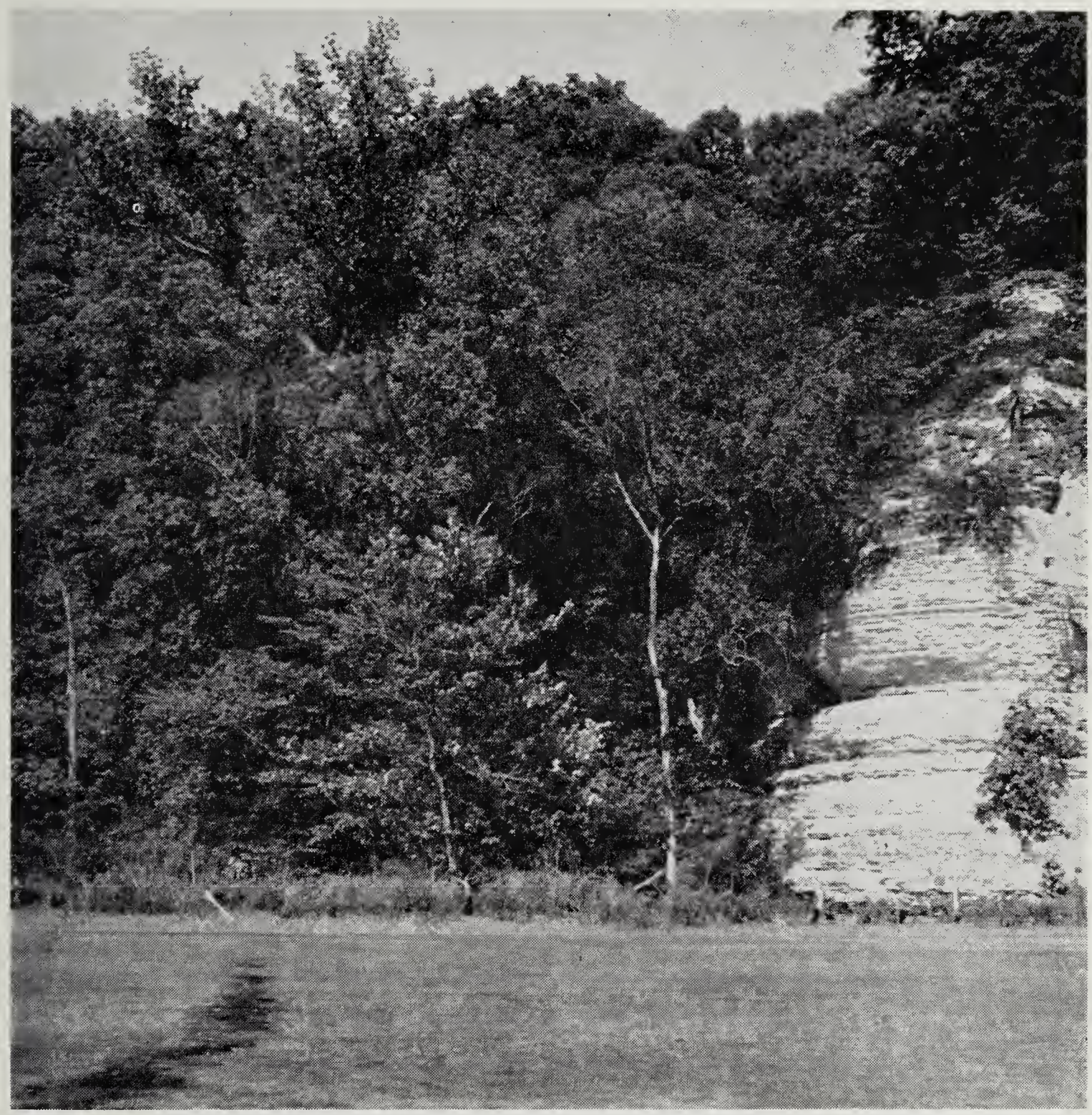

FIGURE 4.—View from a canoe of Otter Pond covered with duckweed and of the fringing buttonbush zone. A path through the duckweed made by the canoe is visible. The Swamp Red Maple - Swamp Cottonwood community is here scarcely represented. The forest shown is the Sweet Gum community with a sweet gum evident as the largest tree in the center of the photo. The Black Oak community is barely evident at the far right on the top of the limestone cliff.

marily of lizard's tail (*Saururus cernuus*). This community does not correspond closely to a Forest Cover Type of North America recognized by the Society of American Foresters (1954).

BOTTOMLAND AND RAVINE HABITATS

Sweet Gum. Sweet gum, which is found in mixtures with a number of associates in varying frequency from location to location, is the indicator tree for this community. Characteristically the associated species include chinquapin oak, tulip tree, sugar maple, elm, bitternut hickory, ash, red mulberry, and sassafras.

TABLE 2.—Tree Canopy Composition of the Forested Communities on the Pine Hills Field Station. For each species the numbers listed show the communities in which it occurs. The bold faced numbers show dominance, or, at least, local abundance. Key: 1. Swamp Red Maple - Swamp Cottonwood; 2. Sweet Gum; 3. Red Oak - Black Gum - Beech; 4. White Oak - Hickory; 5. Sassafras; and 6. Black Oak.

Acer rubrum (Red maple)—2,3,4,5,6.
A. r. var. *drummondii* (Swamp red maple).—1.
A. saccharum SENSU LATO (Sugar maple)—2,3.
Carya cordiformis (Bitternut hickory)—2,3,4.
C. glabra (Pignut h.)—2,3,4,5,6.
C. laciniosa (Shellbark h.)—2.
C. ovalis (Sweet pignut or Small-fruited h.)—2,3,4,5,6.
C. ovata (Shagbark h.)—2,3,4,5,6.
C. texana (Black h.)—6.
Celtis laevigata (Sugarberry)—2.
C. occidentalis (Hackberry)—2,3.
Diospyros virginiana (Persimmon)—2,3,4.
Fagus grandifolia (Beech)—2,3
Fraxinus tomentosa (Pumpkin ash)—1.
F. spp. (white and green a.)—2,3,4.
Gleditsia aquatica (Water locust)—1.
G. triacanthos (Honey locust)—2.
Gymnocladus dioica (Kentucky coffee-tree)—2.
Juglans cinerea (Butternut)—2,3.
J. nigra (Black walnut)—2,3.
Juniperus virginiana (Eastern red cedar)—6.
Liquidambar styraciflua (Sweet gum)—2.
Liriodendron tulipifera (Tulip tree)—2,3,4.
Magnolia acuminata (Cucumber tree)—2,3,4,6.
Morus rubra (Red mulberry)—2,3,4.
Nyssa sylvatica (Black gum)—2,3,4,6.
Pinus echinata (Shortleaf pine)—6.
Platanus occidentalis (Sycamore)—2.
Populus deltoides (Cottonwood)—2.
P. heterophylla (Swamp c.)—1.
Quercus alba (White oak)—2,3,4,5,6.
Q. falcata var. *pagodaefolia* (Cherry-bark o.)—2.
Q. macrocarpa (Bur o.)—2.
Q. marilandica (Blackjack o.)—6.
Q. muehlenbergii (Chinquapin o.)—2,3.
Q. palustris (Pin o.)—2.
Q. rubra (Northern red o.)—2,3,4,5,6.
Q. shumardii (Shumard's red o.)—2.
Q. stellata (Post o.)—4,6.
Q. velutina (Black o.)—2, 3, 4, 5, 6.
Rhus. copallina (Winged sumac)—6.
Salix nigra (Black willow)—1.
Sassafras albidum (Sassafras)—2,3,4,5,6.
Tilia americana (Basswood)—3.
Ulmus alata (Winged elm)—6.
U. american (American e.)—2,3,4.
U. rubra (Red or slippery e.)—2,3,4.

More localized in their occurrence are Shumard's red oak and bur oak, big shell-bark or kingnut hickory, black walnut, Kentucky coffee-tree, honey locust, sycamore, persimmon, and cherrybark oak, as well as occasional representatives from adjoining communities. Within small, local areas groupings of Shumard's Red Oak — Big Shellbark Hickory, or Lowland Bur Oak — Persimmon, or Sugar Maple (in the better drained areas) were found. Understory trees or larger shrubs which form a nearly continuous layer commonly include pawpaw (*Asimina triloba*) and spicebush (*Lindera benzoin* — essentially an indicator shrub), and less commonly, redbud (*Cercis canadensis*), bladdernut (*Staphylea trifolia*) and black haw (*Viburnum rufidulum*). Large vines of grape (*Vitis spp.*) and poison ivy (*Rhus radicans*) are present on trees. An almost continuous, variable, lower, shrubby-herbaceous layer includes the abundant poison ivy (*Rhus radicans*) and a diversity of herbs such as wild ginger (*Asarum canadense*), trillium (*Trillium recurvatum*), Virginia knotweed (*Tovara virginiana*), toothwort (*Dentaria laciniata*), Dutchman's breeches (*Dicentra cucullaria*), and Jack-in-the-Pulpit (*Arisaema triphyllum*). These herbs are distributed irregularly, presumably reflecting both the diverse microhabitats within the forest, and the

FIGURE 5.—A canopy beech in a ravine with the Red Oak - Black Gum - Beech community on the eastern side of the Station.

specific life requirements of individual species.

The Sweet Gum community occupies the areas adjacent to Otter Pond at elevations of approximately two to 15 feet above the water level. It also occupies the floor of the main ravine on the eastern side of the Station where the immediate channel is marked by rocky walls from two to four feet high. It is replaced by other communities in the middle portion of the ravine and may reappear in the narrow, steep-walled heads of a drainage where side slopes reach 40 degrees in slope and 20 feet or more in height. Only one such area is sufficiently large to be included on the map. In explaining such areas, local geologists and for-

esters have suggested a favorable soil condition due to the movement of loess off the ridges into the heads of the drainage systems as well as microclimatic influences.

This community shares some of the characteristics of the Pin Oak-Sweet Gum Forest Cover Type of the Central Forest Region (Society of American Foresters, 1954) and, without the loblolly pine, of the Sweet Gum-Yellow Poplar (*Tulip Tree*) of the Southern Forest Region.

Red Oak-Black Gum-Beech. The Red Oak-Black Gum-Beech community can be considered the "classic" ravine community of the Pine Hills Field Station. It borders the Sweet Gum community and shares species with it to a limited extent. The tree canopy is closed. Larger individuals of several tree species reach nearly 30 inches DBH. Many trees fall in the diameter classes from ten to thirty inches, and smaller size classes are present. A generally discontinuous, small tree-tall shrub layer is present. Herbs are variable, sometimes continuous, while a small shrub stratum is generally lacking. Litter is essentially continuous in summer, less than an inch deep. Rock is occasionally exposed on ravine banks and in the beds of the larger intermittent streams.

The community is somewhat variable in species composition. Red oak is a more consistent component species than black gum or beech. Canopy-size beech, in turn, tends to be exclusively found in this community (Fig. 5). It often occurs as groups of mature trees that may have resulted from earlier cutting practices which left the beech relatively pure in local areas. Black gum may be found within the Sweet Gum community and red oak in the White Oak-Hickory or even in the Black Oak communities. Tulip tree is found frequently in the ravine areas. It is not listed as a name species because of its frequency in the Sweet Gum community as well. Other species are listed in Table 2. Only one American basswood (*Tilia americana*) was found, this on a north-facing side slope. A number of basswood trees were found in two ravines to the north of the Station, though generally it is rare in Southern Illinois.

A lower tree stratum includes sugar maple, flowering dogwood (*Cornus florida*), ironwood (hophornbeam) (*Ostrya virginiana*), winged elm (*Ulmus alata*), redbud, Hercules'-club (*Aralia spinosa*), pawpaw, service berry (*Amelanchier arborea*), wild plum (*Prunus americana*), and blue beech (*Carpinus caroliniana*). Shrubs and woody vines include frequent occurrences of wild hydrangea (*Hydrangea arborescens*), abundant poison ivy, and, infrequently, spicebush. In comparison to the forests of northern Illinois (the Chicago area), a number of expected shrubs absent from this habitat on the Station area included *Viburnum* spp., *Cornus* spp., *Lonicera* spp., *Prunus virginiana,* and *Ribes* spp. The herbaceous layer is relatively continuous. Both Christmas (*Polystichum acrostichoides*) and maidenhair (*Adiantum pedatum*) ferns are common. Many herbs are shared with adjacent Sweet Gum or White Oak-Hickory areas.

FIGURE 6.—White oak (on the left) and hickory (*Carya glabra*) on the right on an upper north-facing slope.

This community is not represented in the Forest Cover Types (1954) except possibly as a variant of the next one here listed.

SLOPE AND RIDGE HABITATS

White Oak-Hickory. The ridge and slope communities are relatively distinct from those of the bottomland and ravine. They are less distinct from one another. Rather consistently associated with the white oak are hickories which key out to *Carya glabra* or *C. ovalis.* Many white oaks exceed 20 inches in diameter, and many hickories 15 inches (Fig. 6). The most important associated species which may reach the diameter of white oak is black oak. Other species found are usually in smaller diameter classes (Table

2). Understory trees frequently include ironwood (hop-hornbeam) and flowering dogwood. Except for the frequent poison ivy the shrub layer, including tree reproduction, is discontinuous. An evident herb layer is present, rarely more than scattered individuals, giving diversity on the otherwise litter-mantled soil. Bottlebrush grass (*Hystrix patula*), desmodium (*Desmodium nudiflorum* and *D.* spp. — also common in the Red Oak - Black Gum - Beech community), wild yam (*Dioscorea villosa*), and *Helianthus divaricatus* — more abundant in the Black Oak community, are frequently found. Few or no herbs are restricted to this community. More are shared with the ridge than with the ravine areas.

The White Oak-Hickory community is found on the north- and east-facing ridge slopes, occasionally on lower south slopes, on ravines which open to the south, or even on a narrow ridge top flanked by well-developed ravines. This may be related to microclimatic influences from the adjacent vegetation. On north-facing slopes it intergrades with the Red Oak-Black Gum-Beech below and the Black Oak community above.

Sassafras. Unlike the other forested areas, this community is characterized by trees of moderate stature. The canopy is essentially closed. Sassafras of about two to three inches DBH predominates, with a sparse admixture of winged sumac of approximately equal stature as the sassafras, of somewhat larger hickories (pignut and small-fruited) and an occasional black or white oak. This community is found on a relatively large flat area at the uppermost contour of the station (800 feet). The suggestion that it represents an old field was neither documented nor fully discarded. The most convincing evidence of possible natural origin was shown by the occurrence of quite similar sassafras stands on other small areas found on south-facing slopes between the Black Oak and the White Oak-Hickory communities. They likewise had admixed small diameter hickories or oaks, a general absence of shrubs, and similar herbaceous species. Explaining them all in terms of old fields seemed unlikely, though logging may have been a factor. For the present, they are simply recognized and one of the largest areas is mapped. No reasonably equivalent type is listed in the Forest Cover Types.

Black Oak. This community encompasses more localized diversity in the canopy species and shrubs than any other except the Sweet Gum community. The herb components are relatively consistent. Black oak, often over 20 inches DBH with several large branches, predominates in a majority of the areas, generally with an absence of other canopy species of equal stature. Sassafras of a few inches DBH usually accompanies and outnumbers the black oak. The Black Oak community predominates on the south- and west-facing slopes and ridges. It may make contact with either the White Oak-Hickory or with the Red Oak-Black Gum-Beech, more so with the latter on south-facing slopes where the Black Oak extends deeper into ravines. Shortleaf pine is found with-

FIGURE 7.—An east-west ridge in December. Snow cover remains on the upper north-facing slope. Little blue-stem is a major component of the ground layer on the south-facing slope under sassafras with scattered small black or white oaks.

in the broad community on localized west- and south-facing steep upper slopes above the Mississippi River trench. Here the characteristic shrub layer includes sparkleberry (*Vaccinium arboreum*) and wild azalea (*Rhododendron roseum*). Black oak is present in these areas. Blackjack oak and post oak are locally frequent in pine areas and on south-facing ridge tops. Hickories, usually considered to be *Carya glabra*, are not conspicuously present in any part of the community. In a further variant on open west-facing rocky outcrops, small eastern red cedar (*Juniperus virginiana*) and ironwood (hop-hornbeam) are found. The understory here includes species of the hill prairies (Evers, 1955).

Grassy areas likewise are found on south-facing ridge tops and upper slopes (Fig. 7).

In the Black Oak community the trees (Table 2) form a relatively open canopy, variable in height as a consequence of the large proportion of small tree species in the canopy. Tall shrubs include occasional sumac (*Rhus copallina*, with some *R. glabra*), and sparkleberry in well-developed pine stands. Small shrubs — New Jersey tea (*Ceanothus americanus*), aromatic sumac (*Rhus aromatica*), and blueberry (*Vaccinium vacillans*) — form occasional thickets; the New Jersey tea is more typical under black oak and the blueberry, under pine. Poison ivy grows less luxuriantly and abundantly in this type, though still the most frequent shrub. Within and adjacent to present pine areas, pine reproduction was conspicuous. The Pine Hills area and a stand in Randolph County thirty miles north represent the only natural occurrences of shortleaf pine in Illinois.

Herbs form a scattered ground cover over most of the type. They are much less evident under the heath cover of several pine stands and are essentially continuous in open grassy woods. Here the main grass is little bluestem (*Andropogon scoparius*) with occasional big bluestem (*A. gerardi*) or Indian grass (*Sorghastrum nutans*). *Helianthus divaricatus* patches may be found in relatively open woods, often with New Jersey tea. Other species are *Solidago ulmifolia, Rudbeckia hirta, Cunila origanoides, Tephrosia virginiana,* and *Dodecatheon meadia.*

Measurements of maximum-minimum temperatures at selected sites from January through early June, 1962, indicate that minimum temperatures in this community differ but little from minima in bottomland and ravine areas. However, as the season progressed, differences in maxima as great as 20 degrees F. between an exposed, west-facing cliff area and a deep ravine were noted. The warmest (and presumably the driest) site supported eastern red cedar, black hickory, blackjack oak, New Jersey tea, and various grasses.

Of the Forest Cover types (Society of American Foresters, 1954) it resembles Post Oak-Black Oak, Shortleaf Pine, and Eastern Red Cedar to some degree. It should be noted that species reported for southern Illinois including southern red oak (*Q. falcata*), shingle oak (*Q. imbricaria*), scarlet oak (*Q. coccinea*), and chestnut oak (*Q. prinus*) were not found on the Station. Southern red and shingle oak are common around Carbondale, and scarlet oak still further east.

Summary

Stereoscopic interpretation of the 1959 U. S. Department of Agriculture aerial photographs at 1:20,000 for the 258 acres of the Pine Hills Field Station showed 50 unit areas. These unit areas were examined by ground survey for their ecological structure, floristic composition, and topographic relations and were grouped in eight plant communities shown on a vegetation map. The Pondweed-Hornwort community was largely composed of submerged aquatics, while species in the Buttonbush community were rooted in areas of standing water. The Swamp

Red Maple-Swamp Cottonwood community is chiefly found in saturated soil or standing water.

Other forested areas were divided into those of lowland and ravine, and of slope and ridge. These correspond roughly to regional forest classifications of southern hardwoods and of oak-hickory. The Sweet Gum community found in lowlands or larger ravines had the largest number of tree species. Above the Sweet Gum community lies the Red Oak-Black Gum-Beech which is characteristically found in ravines and on lower slopes. The White Oak-Hickory community occurs on north- or east-facing upper slopes. Both red and black oaks also are found in the White Oak-Hickory community. An associate in the Black Oak community of south- or west-facing upper slopes and ridges is shortleaf pine. In several areas, one of which was large enough to map, sassafras was the predominant species. These areas may reflect earlier cutting or possible clearing, or fire. The present vegetation has developed with an absence of fire for perhaps 30 years. The aerial photos of 1938 show a more open cover than in 1959. This may also be related to drought.

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CLAY MINERAL VARIATION IN A PENNSYLVANIAN UNDERCLAY

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This report presents the results of a detailed study of the clay mineral composition of a Pennsylvanian underclay which was made while the author was attending the University of Illinois. The underclay crops out along the southeast bank of the Salt Fork Creek, W ½ sec. 31, T 19 N, R 13 W, near the town of Fithian, Vermilion County, Illinois. It occupies a stratigraphic position below the Flat Creek Coal (J. A. Simon, personal communication). This underclay was selected for study since it is the type location for Fithian illite, a standard reference clay mineral (American Petroleum Institute, 1949-50); and also, because it displays features found in many Pennsylvanian underclays.

Following is a description of the stratigraphic sequence and sample positions:

Description	*Thickness in inches*
Shale, black, very hard, fissile, no fossils	8
Shale, black, soft, fissile, contains fossil hash	13
Limestone, dark gray, fossiliferous.	0-6
Coal (Flat Creek)	8
Underclay, dark gray, noncalcareous (sample B7)	5
Underclay, gray, noncalcareous (sample B6 just above iron-stained zone)	5
Iron-stained zone	1
Underclay, gray, calcareous nodules (sample B5 just below iron-stained zone)	10
Underclay, gray, calcareous nodules (sample B4)	10
Underclay, gray, calcareous nodules (sample B3 at base of underclay).	24
Underclay, sandy, calcareous (sample B2 in transition zone)	3
Siltstone, gray, calcareous, thin bedded, micaceous (sample B1 in upper 3 inches of siltstone)	60

Clay Mineralogy

Samples were obtained from freshly cleaned outcrop surfaces. Clay samples from the same stratigraphic sequence were also obtained one-half mile upstream from the type location. Their x-ray traces are similar to those in Figure 1. Each clay sample was dispersed in distilled water and fractionated by sedimentation to remove the < 2 micron size. Oriented aggregates were prepared for x-ray analysis. A General Electric XRD-5 diffraction unit with copper radiation was used. The x-ray traces of unheated, glycolated, and heated samples from the type location are shown (Fig. 1). Samples were heated to 475°C for thirty minutes to distinguish chlorite from kaolinite.

The underlying siltstone is very micaceous, thus giving the intense, well defined peak at 10 a.u. on the x-ray trace. Kaolinite and chlorite are very abundant in the siltstone and decrease as the siltstone grades upward into the base of the underclay (samples B1, B2, B3). The contact between the siltstone and un-

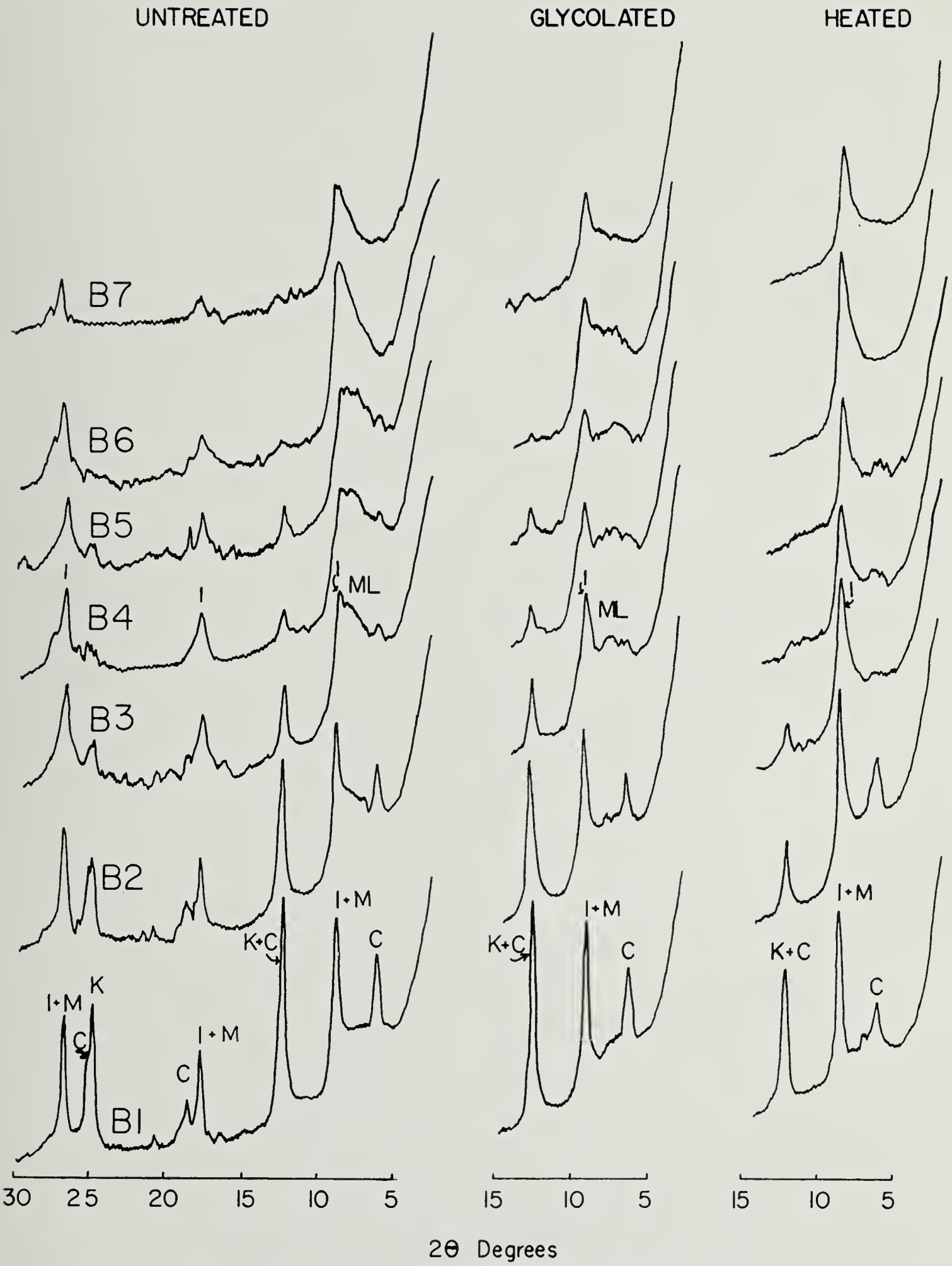

FIGURE 1.—X-ray diffraction traces of oriented clay mineral aggregates arranged in order of stratigraphic position. C, chlorite; I, illite; K, kaolinite; ML, mixed-layer; M, mica.

derclay is transitional as reflected in gradual vertical lithologic and mineralogic changes.

The x-ray traces (Fig. 1) indicate a decrease in the amount of kaolinite and chlorite vertically in the underclay. Illite and mixed-layer minerals dominate. Mixed-layer material slightly decreases in amount vertically, while illite increases. The illite in the noncalcareous zone is not greatly degraded as indicated by an intense and sharp peak at 10 a.u. (Fig. 1, samples B7, B6). An abrupt change in the kaolinite and chlorite content is noted at the iron-stained zone. Below the zone (sample B5), the clay is calcareous and contains mixed-layer minerals, abundant illite, with a minor amount of kaolinite and chlorite. Above the zone (sample B6), the clay is noncalcareous and contains only illite and mixed-layer minerals.

Interpretation

Several explanations accounting for the variation in clay mineral composition are as follows: (a) underclay could represent a fossil soil produced by weathering and leaching (Weller, 1956) which would alter the clay minerals in the same manner as in recent soils; (b) the underclay may have had a detrital origin and the composition variation reflects diagenetic changes; (c) the basin of underclay deposition may have been supplied by various source materials of different composition with no changes produced in the clay material during underclay accumulation.

Many investigators have studied the vertical distribution of clay minerals in soil profiles. Frye, Willman, and Glass (1960) studied profiles in Illinoian till and found an alteration sequence from chlorite and biotite-type micas through vermiculite-chlorite, vermiculite, mixed-layer clay minerals to expandable vermiculite; kaolinite is unaffected and may even be augmented. In buried Sangamon profiles on Illinoian till and outwash, the original illite and chlorite are altered completely in the upper part to montmorillonite (Brophy, 1959). Murray and Leininger (1956) found that illite and chlorite in unweathered parts of Illinoian and Wisconsin tills alter to montmorillonite in highly weathered parts. Droste, Bhattacharya, and Sunderman (1962) found that in soil profiles on glacial till, loess, and limestones the chlorite of the parent material is changed completely to montmorillonite with intermediate stages of random mixed-layers of chlorite-vermiculite-montmorillonite. They stated that kaolinite may be produced as a weathering product or remain unchanged from the parent material.

Dalton, Swineford, and Jewett (1958) studied the clay minerals in a fossil soil zone at a Desmoinesian-Missourian disconformity in southeastern Kansas. The soil zone is developed on top of a marine shale which contains predominantly illite, chlorite, quartz, feldspar, and a very small quantity of kaolinite. The results of alteration in the soil zone show a hydration of illite, characterized by the broadening of the basal reflections, production of "soil" chlorite (i.e., chlorite whose basal spacings are destroyed at 450°C), sporadic increase in kaolinite, and modification and destruction of nor-

mal chlorite (basal reflection retained after heated to 575°C) with production of mixed-layer and vermiculite minerals.

Ostrom and Potter (1961) studied the clay composition of a weathered zone in the Kinkaid Formation at the Mississippian-Pennsylvanian contact in the Illinois Basin. Their evidence indicated that the zone represented a truncated pre-Pennsylvanian weathering profile. The illite in the unaltered part of the formation was found to decrease vertically commensurate with an increase of mixed-layer material. The indication of a structural breakdown of illite to produce the mixed-layer component is used as evidence by Ostrom and Potter to support the existence of a weathering profile.

There are several factors controlling weathering processes which influence soil development: parent rock, topography, vegetation, time, and climate (Grim, 1953). The factors existing during the formation of the underclay of the Flat Creek Coal may have been similar to those influencing soil profile development at the Desmoinesian-Missourian disconformity in Kansas and the Mississippian-Pennsylvanian contact in the Illinois Basin, since the geologic conditions were probably similar in many parts of the Mid-Continent during the Pennsylvanian Period. The latter two profiles formed on dominantly kaolinitic, chloritic, and illitic rocks (a composition similar to the siltstone below the underclay of the present investigation). Since the parent rock and other soil producing factors were probably reasonably similar throughout the mid-continent, the clay mineral composition of the three examples should resemble each other. However, the variation of underclay composition is markedly different from that found in the two examples known to be fossil soils.

There is no indication of a weathering profile similar to that found in Pleistocene deposits. X-ray data of the underclay indicate a decrease upward in the kaolinite and chlorite content, no indication of a hydration or decrease of illite, and no formation of montmorillonite or other three-layer minerals. The mixed-layer component decreases in abundance. The sharp, well-resolved illite peak indicates a lack of degrading which would result under alteration. Grim and Allen (1938) determined the base-exchange values of the Fithian illite underclay and found no similarity to values obtained in a vertical sequence of samples from recent soils showing a profile. The clay minerals in the underclay do not appear to have been altered to produce the composition of those soil profiles formed during the Pleistocene or Pennsylvanian Periods, thus suggesting that the variation in composition probably did not result from the soil forming process.

The underclay may have formed as clay material was deposited in a basin prior to coal swamp development. The clay mineral variation may reflect chemical changes in the environment of deposition, also evidenced by the variation of the calcareous content of the underclay. Kaolinite and chlorite are present in the calcareous part of the underclay but absent in the noncalcareous section. A number of investigators

have found that chlorite increases in a sedimentary environment as the salinity of the water increases (Johns and Grim, 1958; Brown and Ingram, 1954; Powers, 1954). As the source material first comes in contact with more saline water, cation exchange reactions result in the acceptance of K and Mg ions in exchange position. With increasing magnesium content and pH, protons would be subtracted from the water and the brucite configuration would develop. A definite, though poorly crystallized, discrete chlorite phase would develop with increasing brucite growth (Grim and Johns, 1953). The calcareous part of the underclay could have been deposited in a more saline environment in which chlorite could form. Chlorite development probably diminished as the water became fresher, thus indicating why it is absent in the noncalcareous portion.

The variation in underclay composition may be due also to the deposition of source material of different compositions in which less kaolinitic, chloritic, and mixed-layer material were deposited during the accumulation of the upper part of the underclay. The gradual decrease of kaolinite, chlorite, and mixed-layer minerals upward may simply reflect a diminishing of supply of these particular minerals. The supply of illite may have changed only slightly. Thus the variation in composition also may be purely a primary sedimentation feature.

Summary

A detailed clay mineral investigation of the Fithian illite underclay indicates a vertical variation in clay composition. Illite and mixed-layer clay minerals are abundant throughout. Kaolinite and chlorite decrease in amount toward the top of the unit. Clay mineral evidence does not indicate the presence of a profile of a fossil soil. A detrital origin may account for the variation in composition.

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RELATIONSHIPS BETWEEN LENS-WEIGHT, SEX, AND AGE IN BOBWHITES

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Dry weight of the lens has been used as a criterion of age in several species of mammals (Lord, 1959, 1961, 1962; Sanderson, 1961; Kolenosky and Miller, 1962; Beale, 1962). Lord (1959, p. 358) believed that the technique might be used to determine the ages of birds. Payne (1961, p. 339) reported that lens-weights were of little value for determining the ages of house sparrows (*Passer domesticus*) that were more than two months old. He also cited unpublished data which suggested that lens-weights could not be used as a criterion for separating juveniles and adults of pheasants (*Phasianus colchicus*), redwinged blackbirds (*Agelaius phoeniceus*), and scaled quail (*Callipepla squamata*). Campbell and Tomlinson (1962), in a study of lens-weights of pen-reared chukars (*Alectoris graeca*), found considerable overlap in lens-weights of juvenile and adult birds, but a significant difference between mean lens-weights of the two age classes. They found no significant difference between mean lens-weights of 1-year old and 2-year old birds. The paucity of published material concerning lens-weight to age relationships among birds, particularly among wild game birds, appears to warrant further research.

Methods

A sample consisting of the head and one wing from each of 135 bobwhites (*Colinus virginianus*) was collected during the first 12 days of the 1962 hunting season (November 17-29) from six counties in southern Illinois. Because there is evidence that freezing may cause changes which affect the dry weight of the lens (Montgomery, 1963, p. 481), precautions were taken to prevent freezing of the heads. Eyes which were intact were removed from the heads on the day of collection and preserved in vials in a 10 percent formalin solution. After storage in formalin for two months, lenses were removed from the eyes and dried in an electric oven at 80° C for 48 hours. Vials containing the dried lenses were stoppered immediately after removal from the oven to prevent the lenses from absorbing moisture from the air. Remnants of the ciliary membranes were removed from the lenses by tapping the vials against the palm of the hand; a few lenses were chipped by this process. Lenses which appeared to be pitted or chipped were discarded. Dried lenses were weighed on a Roller-Smith precision balance to the nearest 0.1 mg.

Sex of the bobwhites was recognized by the plumage of the head and neck. Exact ages of the bobwhites were not known. Juveniles were distinguished from adults by the presence of the buffy fringe on the tips of their primary coverts; ages of juveniles were estimated by the sequence of the molt and replacement of the primary wing feathers (Petrides and Nestler, 1952, p. 109). Because of small numbers of specimens less than 150 days old, juveniles were separated into only three age classes (65-105 days; 111-149 days; 150 days or older) for purposes of analysis.

Results

Weights of 87 pairs of lenses and 38 single lenses were available from the original sample. Eight pairs, in which the weights of individual lenses differed by 1.0 mg or more, were discarded because such large differences in weight probably were caused by absorption of moisture from the air, weighing errors, or unnoticed chips in one of the lenses. The mean difference in weight between the two lenses of the remaining 79 pairs was 0.3 $\pm$ 0.05 mg. Data for 117 birds were obtained from the mean weight of the two lenses from 79 bobwhites and from weights of single lenses from 38 bobwhites.

Payne (1961, p. 339) reported no apparent difference in the lens-weights of male and female house sparrows. In contrast, Campbell and Tomlinson (1962, p. 407) found lenses of male chukars to be significantly heavier than those of females. Among adult bobwhites, and among juvenile bobwhites more than 150 days old, lens-weights of males were significantly heavier than those of females ($P<0.001$). Because the mean growth rate of the lenses of bobwhites decreases with age (Table 1) we believe that differences in lens-weights caused by differences in age within these groups is overshadowed by differences due to sex. Numbers of lens-weights from birds in the 65-105 day old and the 111-149 day old groups were too few for similar analyses of differences in lens-weights of the two sexes (Table 2).

Mean lens-weights of the various age classes of bobwhites are compared in Table 1; t tests indicated significant differences ($P<0.05$) between all adjacent age groups. Identical tests between age groups segregated by sex disclosed similar differences in all comparisons except between the 111-149 day old and the 150 or more day old groups among females.

A frequency distribution of lens-weights (Table 2) revealed that 70.6 percent of the lens-weights of juvenile bobwhites exceeded the lightest lens-weight of an adult, and that 20.6 percent exceeded the mean lens-weight of adults.

We interpret data in Tables 1 and 2 to indicate a direct lens-weight to age correlation among bobwhites. The degree of overlap in the ranges of lens-weights between age groups appears to be too great for lens-weights to be used as a satisfactory criterion for determination of age. It appears possible, however, to use lens-weight data in comparative studies of age composition of different populations.

TABLE 1.—Analyses of Lens-weights of Various Age Classes of 117 Bobwhites Taken in Southern Illinois, November 17-29, 1962.

Classes Compared	N (birds)	$\overline{X}$ (mg)	$\overline{X}_1 - \overline{X}_2$ (mg)	s (mg)	Range (mg)	*t*	Level of Significance $\overline{X}_1 - \overline{X}_2$
65-105 days:	11	7.1		.934	5.0-8.3		
111-149 days.....	27	8.0	0.9	.720	6.4-9.4	6.92	0.999
111-149 days:	27	8.0		.720	6.4-9.4		
150+days[1]	64	8.5	0.5	.704	6.8-10.0	4.78	0.999
150+days[1]:	64	8.5		.704	6.8-10.0		
Adults	15	8.8	0.3	.760	7.8-10.1	2.23	0.95
Juveniles:	102	8.2		.850	5.0-10.0		
Adults	15	8.8	0.6	.760	7.8-10.1	3.03	0.99

[1] Maximum age of any individual in this group would not be expected to exceed 200 days.

TABLE 2.—Frequency Distribution of 117 Lens-weights of Bobwhites Taken in Southern Illinois, November 17-29, 1962.

Lens-weight classes (mg)	Age classes			
	Juveniles[1]			Adults[1]
	65-105 days	111-149 days	150+ days	
10.0-10.3			X	O
9.6-9.9			XXXXO	XXO
9.2-9.5		OO	XXXXXX	X
8.8-9.1		XXO	XXXXXXOO	X
8.4-8.7		XO	XXXXXXXXXOOOOOOOO	OOO
8.0-8.3	XO	XXXOOO	XXXXXXOOOOOOOOOO	XOOOO
7.6-7.9	XX	XXXOOOOO	OOOO	O
7.2-7.5	O	XO	XOOO	
6.8-7.1	XOO	XXO	XOO	
6.4-6.7	O	X		
6.0-6.3	X			
5.6-5.9				
5.2-5.5				
4.8-5.1	X			

[1] Males indicated by X; females by O.

SUMMARY

Analyses of dry weights of lenses from 117 bobwhites collected in southern Illinois during November, 1962, indicated that lens-weights of males were significantly heavier than those of females among adults and among juveniles 150 or more days old. Mean lens-weights of various age groups were significantly different, indicating a direct correlation between lens-weight and age. The degree of overlap in ranges of lens-weights between age groups appears to be too great for the lens-weight technique to be used to determine age of individual bobwhites.

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NEWS AND NOTES

"News and Notes" has been a part, off and on, of the Transactions. This section, phoenix-like, will not stay inactive so why not keep the thing flourishing by sending in news and comments of interest to Academy readers to the editor or to the Illinois State Museum. It is only fair to point out that the space available in each issue will determine the length of the section.

New Sections at the Annual Meeting — Ten participants can form a new section for the Annual Meeting. Anyone interested in forming or being a part of a new section should write to John C. Frye, Illinois State Geological Survey, Urbana. However, do so promptly, because it takes time to arrange a program.

May I call to your attention the reprinting of G. S. Chappell's "Through the Alimentary Canal with Gun and Camera . . ." in order that you may enjoy again the "Gathering of the Glands" and "the magnificent band . . . playing 'The Calomels are Coming'."

G. H. Cady receives Thiessen Medal — G. H. Cady, senior geologist, emeritus, with the Illinois State Geological Survey, was awarded the Thiessen Medal by the International Committee for Coal Petrology, the science of the physical makeup of coal, at a conference in Paris, France, September 10.

Dr. Cady, who was head of the Survey's coal section from 1926 to 1951, was the second person and the first American to receive the award. The medal, named for Dr. Reinhardt Thiessen, pioneer coal petrologist and for many years in the U. S. Bureau of Mines, was created about 10 years ago and is given for service in the field of coal petrology. A previous award went to C. A. Seyler of England and Eric Stach of the Geological Survey of Germany, Krefeld, received the third award.

The medal was presented at the meeting of the International Committee in connection with the Fifth International Conference on Carboniferous Stratigraphy and Geology.

Dr. Cady instituted a program of coal petrology at the Illinois Geological Survey over 30 years ago, and the field is only now becoming widely applied. Except for the U. S. Bureau of Mines, the Illinois Survey has had a continuous program in coal petrology longer than any other organization in the country. He trained many people in coal geology who are now prominent in the U. S. Geological Survey, other state Surveys, in the teaching field, and in industry.

Dr. Cady is no stranger to the Illinois Academy of Science, being a faithful participant at annual meetings and possibly our oldest member. (Those last few words will get

me an item for the next "News and Comments.")

Dr. Joseph R. Caldwell, Head Curator of Anthropology at the Illinois State Museum, has received a ten month's Fulbright grant for lecturing and research in Iran.

He is lecturing at the University of Teheran and is doing field work in an ancient valley, now dry, in the easternmost parts of Iran.

Mrs. Caldwell and their four children have accompanied him.

Dr. Caldwell plans to return to the Illinois State Museum in June of 1964.

PREPARATION OF MANUSCRIPTS FOR THE TRANSACTIONS

For publication in the *Transactions*, articles must present significant material that has not been published elsewhere. Review articles are excepted from this provision, as are brief quotations necessary to consider new material or varying concepts. All manuscripts must be typewritten, double spaced, with at least one-inch margins. The original copy and one carbon copy should be submitted.

Titles should be brief and informative. The address or institutional connection of the author appears just below the author's name. An abstract must accompany each article. Subtitles or center headings should be used; ordinarily one uses subtitles such as *Materials*, *Methods*, *Results*, *Discussion*, *Summary*, *Acknowledgments*, and *Literature Cited*.

No footnotes are to be used in the text.

The section entitled *Literature Cited* must include all references mentioned in text. It is not to include any other titles. No references to the literature are to be placed in footnotes. Citations under *Literature Cited* are as shown below:

Doe, John H. 1951. The life cycle of a land snail. Conchol. 26(3): 21-32, 2 tables, 3 figs.

Doe, John H. 1951. Mineralogy of Lower Tertiary deposits. New York, McGraw-Hill Book Co. iv + 396 pp.

Quoted passages, titles, and citations must be checked and rechecked for accuracy. Citations to particular pages in text are Doe (1908, p. 21) or (Doe, 1908, p. 21); general citation in text is Doe (1908) or (Doe, 1908).

Tabular information should be kept at a minimum. Tables should not be more than one page in length. Do not duplicate tabular data in text. Headings for tables and columns should be brief. Reduce to the barest essentials, or preferably omit, explanatory notes on tables. Each table and its heading should be on a single page; do not place any table on the same page with text.

Photographs should be hard, glossy prints of good contrast. Graphs, maps and other figures reproduce best when prepared for at least one-half reduction; lettering, numerals, etc. on all figures in a manuscript should be worked out to proper size for such reduction. Line widths, letter size etc. should be uniform from figure to figure within a published paper. Figures should be drawn on good quality white paper or on drawing board. Use only India ink. Use a lettering device (Leroy or Wrico) for numerals and words; do not print "free-hand."

Legends for photographs and figures should be brief; type them on a separate sheet of paper. Indicate figure number and your name on back of illustration; do not write with pencil on the backs of photographs.

Authors will receive galley proofs; these should be read carefully and checked against the original manuscript. Reprints may be ordered at the time galley proofs and manuscripts are returned to the Editor.

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ILLINOIS
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